# GRADUATE ENGINEERING TRAINING

Western Electric Company
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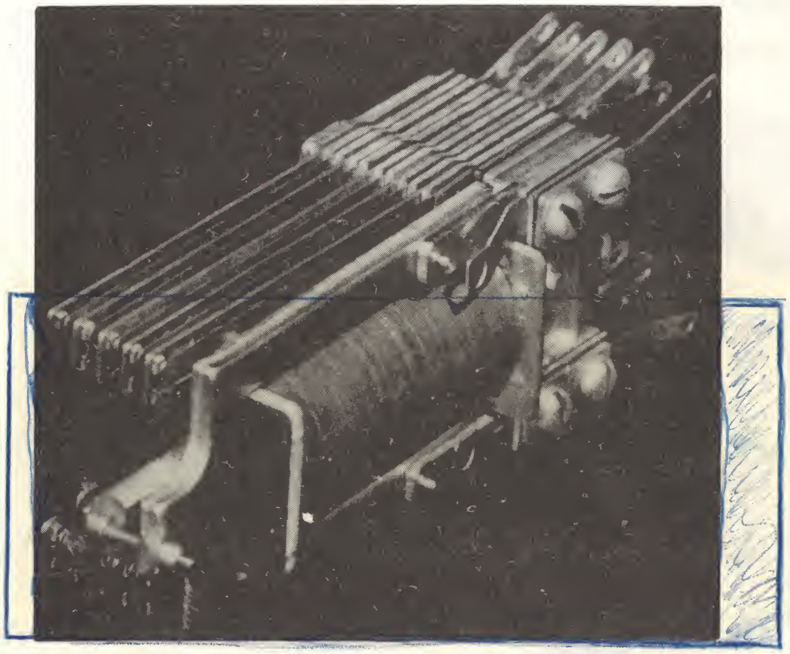
Western Electric Co., Inc.
Hawthorne Works
Industrial Relations Branch
Training Department

Information Pamphlet 2.1-102
For Training Purposes Only

# THE U-TYPE RELAY



In the past, the most widely used relays in the telephone plant have been of the flat type. These have proved economical to manufacture; and experience extending over a quarter of a century has testified to their satisfactoriness in operation. During this time, however, the telephone system has changed, and upon relays there have been imposed operations more complicated and critical than were in mind at the time of their development. Materials and manufacturing methods also have changed, so that all in all it seemed desirable a few years ago to undetake the design of a new all-purpose relay. The U-type relay - shown in the photograph at the head of this article - is the result.

Reliability in relay operation has become of increasing importance in recent years. The intricacies of the dial systems require the operation of a large number of relays on each call, and for the satisfactory functioning of the system many of these relays must operate and release at just the right time and without fail. The existing types of relays do this, of course, with what is really remarkable precision, but occasionally a speck of dirt will get between the contacts to prevent their closing. Also the contacts may "chatter" - rapidly opening and closing as a result either of the rebounding of the armature when the relay is de-energized, or of the independent vibration of the springs. One of the objectives of the new design, therefore, was to improve reliability by making dirt particles less effective, and by reducing the tendency to chatter. Another objective was to secure a greater number of contact springs per relay. A study indicated that an increase from the twelve springs of the present relay to twenty-four would be satisfactory. To obtain the full advantage of such an increase, however, the gain in number of contacts must not be offset by an corresponding increase in size or in energy required. In other words, more effective and efficient use of materials was sought.

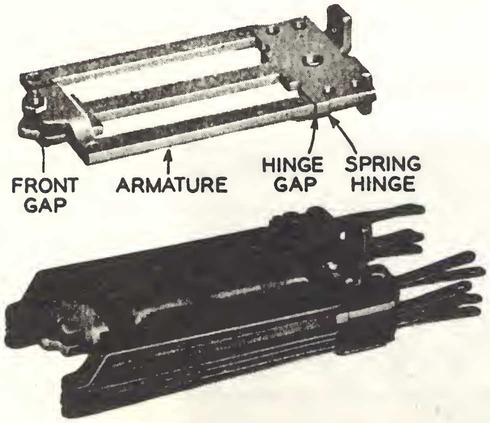



Fig. 1 - The armatures of the E- and R-type relays are hinged to the core by a short strip of magnetic iron, which may be seen in the photograph of the relay, and in the diagram of its magnetic circuit.

An increased number of contacts requires a larger magnetic flux; and if the energy consumed by the winding is not to be increased, this flux can most effectively be secured by providing a magnetic path of lower reluctance. Such an improved magnetic path was secured, first, by using a larger core of circular cross-section, which provides the greatest flux for a given length of wire; and second, by reducing the air-gap reluctance and making more advantageous use of it. In both the E-and R-type relays, which are of the flat type, a U-shaped armature is hinged to the yoke at the rear of the core by a piece of thin magnetic iron, as shown in Figure 1. The spring hinge is so thin that only a small part of the flux can be carried by it; the rest of the flux passes through air, which introduces into the circuit an additional reluctance that serves no useful purpose. The gap at the hinge is kept as small as possible, of course, but it must be large enough to permit free movement of the armature after allowing for unavoidable unevenness at the hinge.

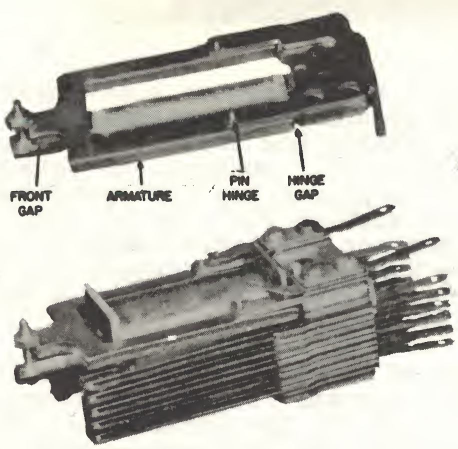



Fig. 2 - With the U-type relay a loosely pivoted hinge is employed, and the air gap at the rear becomes a long narrow wedge. This is evident in the photograph and in the diagram of the magnetic circuit.

The armature of the new relay is of the same U shape as that of the R-type relay, but overlaps the end yoke, instead of being hinged to it, and is held loosely in place by a pin in each arm of the U. The construction is shown in Figure 2. In its unoperated position, the armature pivots on the front edge of the rear bracket - leaving a long wedge-shaped air gap between this edge and the rear end of the armature. As the armature closes, this wedge-shaped air gap narrows down until, in the operated condition of the armature, it almost disappears. This form of mounting tends to introduce only a small reluctance, which is made still smaller by the comparatively large cross-sectional area of the hinge gap as compared with former relays. Moreover, the flux in this gap performs a useful function, since the resulting force of attraction on the rear end of the armature tends to rotate the armature around the pivoting point in the same direction as does the relatively greater pull at the gap at the front end. The core is milled flat at its rear where it fastens to the cross yoke, and also at its front to form a broad flat surface for the armature. This front gap is limited in width by the diameter of the core, but it is made long enough to give a large area and thus a low reluctance.

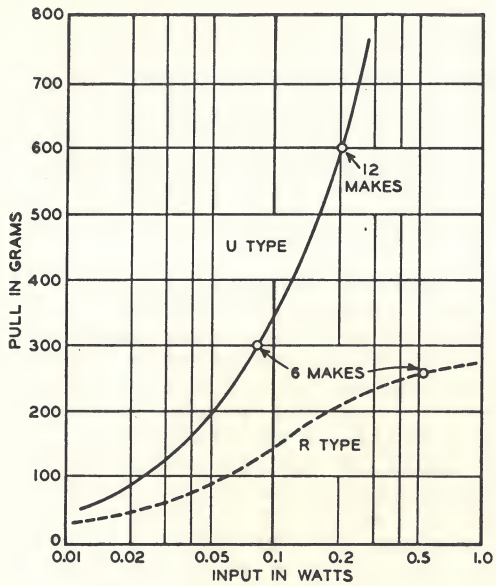



Fig. 3 - Relationship between pull and watts for both the R- and U-type relays.

How effective this construction is in increasing the pull is shown by Figure 3, which gives a typical relationship between the force which the armature can develop, and the power required to maintain this force, for both the R- and U-type relays. The pull provided for six make contacts is somewhat greater for the U-type relay than for the R - more contact pressure being provided - but the power required is only about a fifth. The R-type would be incapable of closing 12 make contacts, while the U-type closes them with less than half the power required by the R-type.

Besides contributing to the pull of the relay, this construction tends to reduce the likelihood of chatter caused by the armature rebounding after it has opened. With the reed-hinged armature of former relays, the full force of the rebound occurs at the front end of the relay where the tendency to close the contacts is great. With the U-type relay, however, the rebound divides between the front gap and the loosely mounted pivoting point farther back; and the net consequence at the contacts is far less than if the armature were free to recoil only at the front.

Of at least equal importance is the chatter caused by vibration of the springs. Considerable study, both theoretical and experimental, was necessary to determine the nature and causes of this vibration and the best method of its elimination. It was finally found that by properly proportioning the dimensions of both the stationary and the movable springs this form of chatter could be eliminated as a source of serious trouble.

The other major improvement incorporated in this new relay is the use of twin contacts. Each contact spring carries two separate contacts in parallel, so that even though one of them should be held open by a speck of dust, the other would close. As already noted, the failure of a relay to make contact is of comparatively rare occurrence, but the provision of double contacts very greatly decreases this likelihood. The probability of a random failure when two parallel contacts are employed is the square of the probability for a single contact. If, for example, a single contact fails to make once in ten thousand times, then a pair of contacts in parallel under similar conditions will fail only once in a hundred million times.

With these various improvements a relay has been made available that, besides being able with less power to close twice as many contacts as the R-type, is practically free from chatter and from contact failure. In designing the U-type relay every advantage has been taken of past experience and of recent developments, not only to make it more effective but also to keep its manufacturing cost low. With this in view a striking change was incorporated in the method of winding. In previous relays the front and rear of the core are larger than the section on which the winding is placed, and the wire for the coil is wound in place on the core. With the new relay the core has been made of the same diameter throughout its length so that it is possible to wind the coils

separately and then slip them over the cores. This change in the core was adopted largely to take advantage of a method of winding coils in multiple which was developed by the Western Electric Company. On a single arbor, as shown in Figure 4, eight coils are wound at the same time from eight spools of wire. Between adjacent windings are slight separations so that they may be cut apart when completed. Between successive layers of wire are very thin layers of cellulose acetate sheet, which run the full length of the arbor and hold the wire in place.

The collection of spring contacts consists of stationary and movable springs, separated in their mounting by strips of insulation. The stationary ones are considerably thicker than the movable, and do not bend appreciably as the relay operates. The movable springs are controlled by the armature thru insulating rods, which are fastened to alternate springs and pass through openings in the stationary springs. The general appearance of a spring assembly for twelve make contacts, which is the full complement of a relay, is shown at the head of this article. Each stationary spring is a single piece with the two contacts near the ends. The movable springs are forked a little beyond the point of attachment to the operating rod, with each branch carrying one contact. This gives comparative independence between the two contacts of a pair, so that if one is held open the other will still be free to make contact. The soldering terminals of these springs fan out at the rear in the usual manner. For the windings, soldering terminals are similarly arranged, but they are also extended toward the front of the relay. This arrangement gives access to the windings when testing from the front.

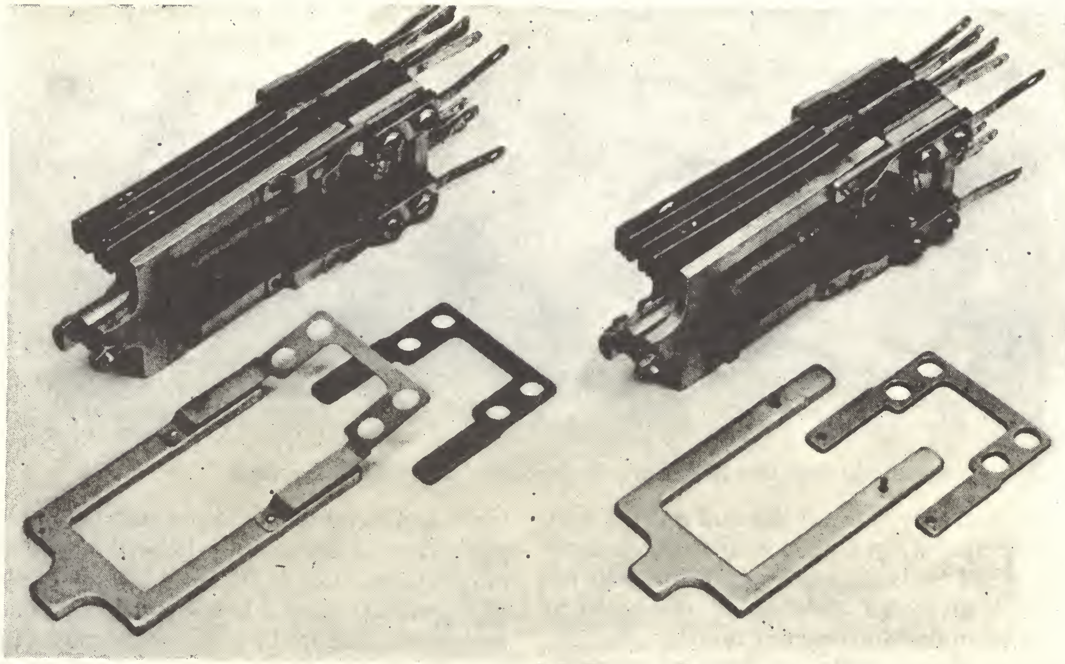
The headpiece illustrates a relay provided only with make contacts but, as with most relays, other combinations may be built up, such as break-contacts, make-before-break, break-before-make, or make-before-make; several hundred combinations may be obtained. For the windings also there is a large number of possible ratings depending on the voltage of the circuit in which the relay is to operate and on other circuit characteristics or on the type of operation required. Other optional features are copper and aluminum sleeves which are slipped over the core when slower operation is desired, and a split permalloy sleeve to give the winding a high impedance to voice frequencies. The cores are usually of magnetic iron, but permalloy may be used when conditions warrant it.

Because relays are used in large numbers, their space requirement becomes of considerable importance. The U-type requires vertically the same space as the flat relay; and horizontally, space determined by

Fig. 4 - For the U-type relays eight separate windings are wound on a single arbor and then cut off and assembled over the core.

its number of springs. When equipped to capacity, it has a spring-pair density in the plane of the mounting rack of 4.2 pairs per square inch, while the greatest density before, which was with the R-type, was 3.4 pairs.

Development of this relay had its inception in the need for more contacts and for lower battery drain; but in the course of its design it was found possible to add many other desirable features, such as twin contacts and freedom from chatter. As a result, it has become of much wider utility than was originally anticipated.



Western Electric Co., Inc.
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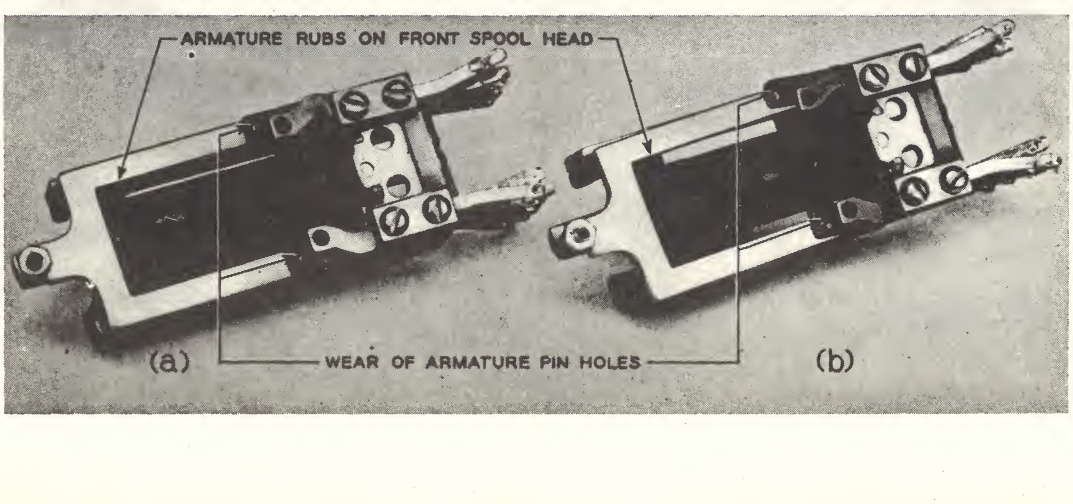
# *Improved U, UA, and Y type relays*

As telephone traffic increases and costs of providing service increase, concentrated efforts are being made to hold down operating costs without impairing the quality of the service. One area of attention has been that of U, UA, and Y type relays, where recent circuit needs have imposed more difficult requirements on these relays.

The new No. 5 crossbar system, automatic message accounting, and greater use of unattended offices have produced a demand for higher operating speeds, longer life, and greater adjustment stability of these relays. Prior to, and during World War II, the relays used in the No. 1 crossbar system were not required to have operate times of less than

*Fig. 1 (at top of page)—The reed type hinge on the left now replaces the pin type hinge, right.*

*Fig. 2 (a)—After 100 million operations, wear of the armature pins has allowed the armature to drop and rub on the front spoolhead. (b) After bending the armature pin bracket, the relay was good for another 100 million operations.*



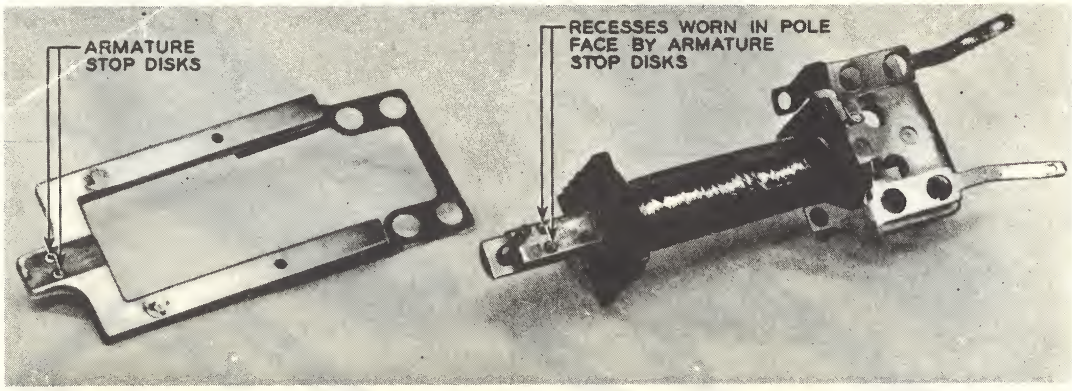



*Fig. 3—Wear of the stop pins and core pole-face after* 50 *million operations.*

ten or fifteen milliseconds and did not have to operate in any case more than two or three hundred million operations during their life —in most cases, only about one-tenth as many. In the No. 5 system, however, the useful life of some of the relays must be as many as one billion operations over a period of 40 years, and with speeds as fast as five milliseconds.

To attain the increased life, faster speeds, and greater numbers of operations, several changes have been made in design. One of these was the development of a reed type hinge suspension for the armature to replace the older pin type, as shown in Figure 1. While the pin type armature hinge is fully satisfactory when the U relay is used in the original No. 1 crossbar circuits, in the new circuits, the much larger number of operations and the higher speeds of operation made it necessary to use the reed type hinge. With the pin type hinge, the rubbing action of the pins wore grooves in the holes of the hinge bracket, causing the front end of the armature to drop until eventually the top inner surface of the armature rubbed on the top surface of the front spoolhead, resulting in faulty operation of the relay. This is shown in Figure 2(a), on a U relay after approximately one hundred million operations. The associated relay, Figure 2(b), is one that had failed at about the same number of operations, but was made serviceable by bending the hinge bracket so that the front end of the armature was restored to its normal position. Then, after operating the relay another 100 million times, the additional wear of the hinge bracket holes allowed the armature to drop and touch the front spoolhead again. By this time, the useful life of the relay had ended.

Similar relays provided with the new reed hinge have been operated over a billion times under the same conditions, without showing fatigue of the reed hinge and with no dropping of the armature. This hinge is now in regular production on U, UA, and Y relays.

Another effect of the increased number of relay operations and higher speeds de-

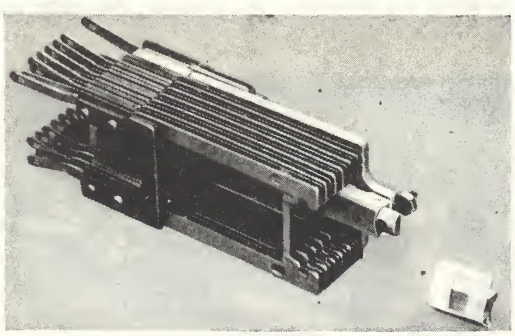


*Fig. 4—Improved relay life is obtained with a Teflon separator.*

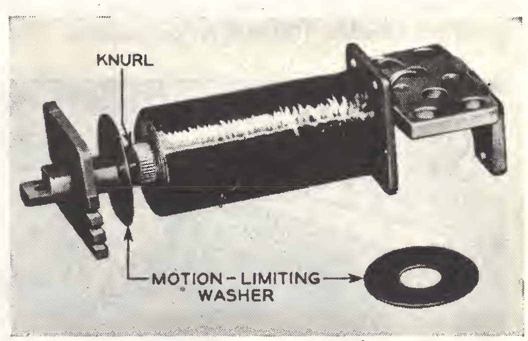



*Fig. 5—Motion limiting washer for relay coils fits snugly over the core.*

manded by new circuits, lies in the wear at the pole faces of the armature and core. Most relays are provided with small, non-magnetic discs welded to the armature pole-face, used to provide a space between the armature and core when the relay is operated. These "stop discs" serve two purposes—to reduce the effect of residual magnetism that tends to hold the relay operated when power is removed from the winding, and to provide a desired release time of the relay. On relays equipped with low resistance windings and having large armature travels, the armature strikes the core at a relatively high velocity, with the result that the stop discs not only show wear themselves, but also pound into the core pole-faces. Under the most severe operating conditions, the air gap may be entirely gone on some of the relays after 50 million operations and the armature pole-face then strikes the core pole-face—a condition that increases the effect of residual magnetism in slowing the release of the relay, or even causing failure to release. Figure 3 illustrates such a relay, showing the impressions in the core pole-face made by the stop discs and also indications of actual contact between armature and core pole-faces. The latter may be seen as bright spots at the tips of the pole-faces in the photograph.

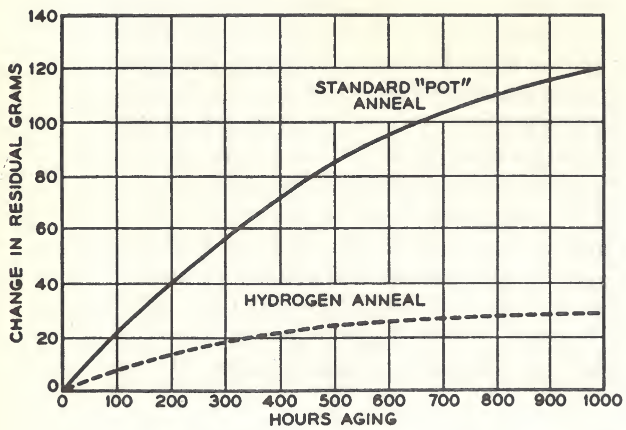



*Fig. 6—Comparison of standard "pot" anneal and hydrogen anneal.*

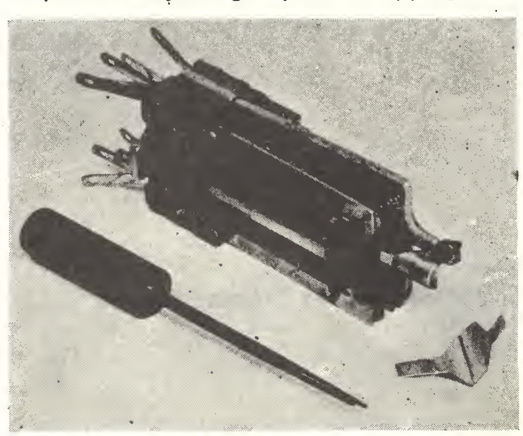
To overcome this source of trouble, a wear pad made of a new plastic called "Teflon" has been developed. This pad or separator is designed so that it can be applied to the relay either during its assembly in the factory or on the relay in the central office. Figure 4 shows a relay with the separator installed, and a separator alone. The slot is provided to clear the stop discs already in place on the armature.

Laboratory tests have shown that the relay may be operated more than 500 million times before any appreciable wear of the separator occurs. When the wear reaches an amount that might affect the release time of the relay, it is a simple matter to remove the old separator and install a new one.

Besides the new separator, improved life of the stop discs has been achieved by changing the metal of which they are made. Previously, the stop discs were of nickel silver, but tests have shown that the use of an alloy of gold, silver, and platinum—previously used only for electrical contacts—doubled the useful life of the stop discs. For some relays, this change in stop disc material enabled the relay to meet the new life requirements without adding the Teflon separator.

The spring studs used to operate the relay springs are also subject to wear. This causes loss of contact "follow," reducing the force between contacts that close on relay operation, and making the separation less between contacts that open when the relay operates. If this continues far enough, the relay will fail in its circuit function. The studs were made originally of hard natural rubber, but studies have shown that a synthetic rubber containing a graphite mixture has wearing characteristics two or three times better than

*Fig. 7—The magnetic separator is fastened to the pole-face by using a special wrapping tool.*



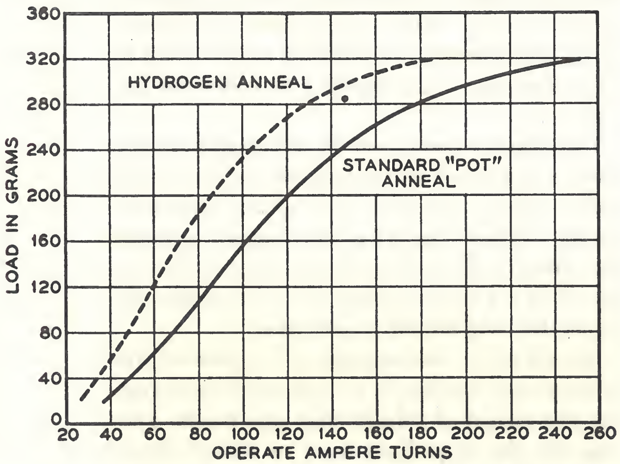



*Fig. 8—Increase in pull of a typical UA relay due to annealing the magnetic parts in hydrogen.*

those of the natural hard rubber. The graphited synthetic rubber is now being used for all new relays.

With the increased speed of operation of the relays, the coils are subject to much greater vibration than heretofore, and this has introduced the possibility of lead breakage. Such breakage is due principally to fatigue, when there is some looseness of the coil on the relay core, and the impact of the armature against the core pole-face produces lateral displacement of the coil at the front or non-terminal spoolhead. This movement has a tendency to bend the leads sufficiently to cause them eventually to break as a result of fatigue. To eliminate this movement, a motion limiting washer has been provided to fit snugly over the core and which is bonded to the end of the coil. Figure 5 illustrates the washer and the way it is used. In assembly, the washer and front spoolhead are pushed over the knurl on the core and the washer is bonded to the front end of the coil. The tight fit of the washer on the knurl is the feature that prevents lateral movement of the coil. There is always some slight shrinkage of the cellulose acetate in the longitudinal direction of the coil, but the washer can move with the coil, although eliminating lateral movement. Use of this washer has practically eliminated lead breakage from fatigue.

The Y type relay was designed to provide time delay on release. Over a period of years, it was found that the release characteristics of some of these relays had changed—in some cases, the relays would fail to release at all. Investigations showed that over a period of time, the coercive force of the magnetic iron increases, and with the relatively closely coupled magnetic circuit of this relay, the residual magnetism increased to a value in excess of the spring tension restoring force.

This aging effect can be practically eliminated on new relays by heat treating the magnetic parts in an atmosphere of hydrogen, and this is being done on UA and Y type relays. Figure 6 compares the effects of aging on residual magnetic force of the

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standard "pot" anneal with the newer hydrogen anneal. For Y relays already in service, however, and therefore subject to aging effects, a magnetic separator has been developed that will reduce the residual force sufficiently to enable the relays to meet their adjustment requirements. This is a small nickel detail as shown in Figure 7, that can be wrapped around the core pole-face, using the special tool illustrated.

Besides greatly reducing the effect of aging, hydrogen annealing increases the permeability of the magnetic iron by a large amount. This is shown by the typical curves of Figure 8, where the pull of a UA relay has been increased as much as 50 percent. This gain is of particular importance on the UA relay, since this relay, having a larger pole-face area than that of U and Y type relays, and consequently having a lower reluctance magnetic circuit, is more susceptible to variations in permeability of the iron. The importance of aging or of poor quality iron is thus reduced by means of hydrogen annealing.

Telephone central office switching apparatus is unique in many respects. Designs are based upon requirements in existence, or anticipated, at the time the designs are prepared, but very often, advances in technical developments introduce unforeseen difficulties. Besides, increased telephone traffic may demand speeds of operation not previously considered, and problems of life and wear of the apparatus appear. The several improvements described in this article, therefore, indicate only a few of the objectives that engineers are constantly working toward to maintain and to improve telephone service.

Western Electric Co., Inc.
Hawthorne Works
Personnel Service Branch
Training Department

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# The UB relay

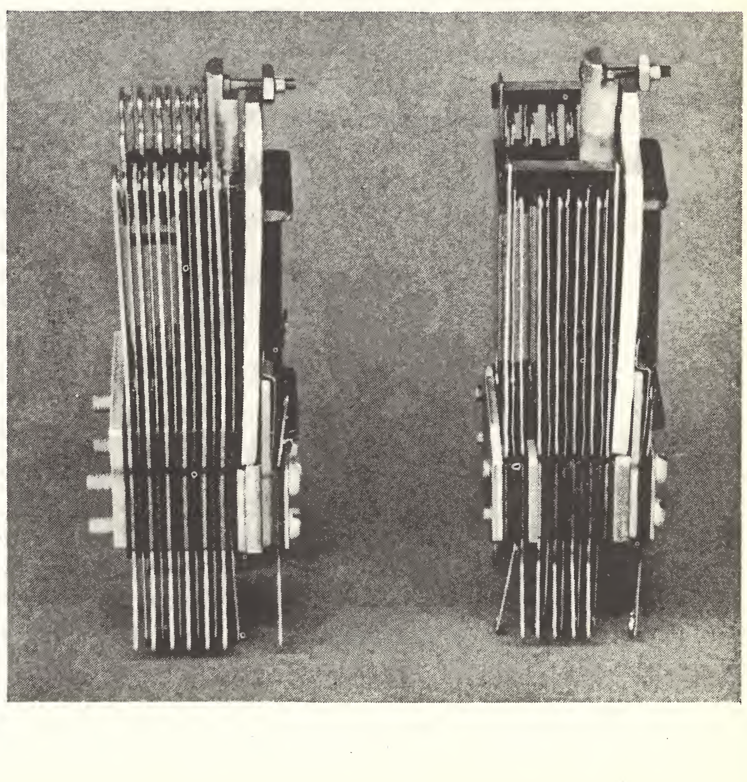
In a crossbar dial office there are in the neighborhood of 70,000 relays for 10,000 subscribers' lines. More than half of these are of the U type. The UB relay has recently been introduced, on a limited basis, as a replacement for the U where freedom from locking contacts and stability of adjustment are of particular importance. Its major field of application will be where the number of operations is high—of the order of several millions a year or more. At the present time, it is used extensively in the new automatic message accounting system, where relay operations exceeding twenty-five millions annually are quite common. Although in appearance and major structural features the UB is essentially the same as the U, Figure 1, and the two relays are interchangeable physically, they are not always the same circuitwise. Because of this, the UB is being restricted initially to those applications where its characteristics are of particular advantage.

The advantage of the UB lies in the method of actuating the contacts. With make contacts of previous relays, the spring carrying the moving contacts is tensioned away from the fixed contact on the spoolhead spring, and exerts a force to hold the armature against the back-stop when the relay is unoperated. A stud, moved by the armature, presses against the contact spring a short distance back of the contact to close the contacts when the relay is operated. This is indicated in the upper part of Figure 2 for a single set of contacts.

In contrast with this arrangement, the UB relay employs a phenol fibre card instead of a stud to operate the contacts, as shown in the lower part of Figure 2. The moving contact spring itself is pretensioned against the fixed contact to give the desired contact force of between 20 and 30 grams. The card is held by two card springs that are tensioned away from the fixed contact, and in slightly greater amount than the moving contact spring is tensioned toward it. As a result, when the relay is unoperated, the card holds a make contact away from the fixed contact. When the relay operates, the armature pressing against the top of the card pushes it toward the fixed contact, and thus allows the contact to close. A break contact on the UB relay is identical with the make, except that the card opens the break on operation of the relay and permits it to close on release. No balancing force is needed in this case.

It will be noticed that with previous relays, as indicated in the upper part of Figure 2, the deflection of the contact spring in closing slightly tilts the moving contact with respect to the fixed contact. This is also true when the contact opens, and thus in both closing and opening there is a small component of relative motion of the contacts perpendicular to the direction of motion of the armature; the contacts slide in being pressed together.

*Fig. 1—U relay at the left and UB at the right*



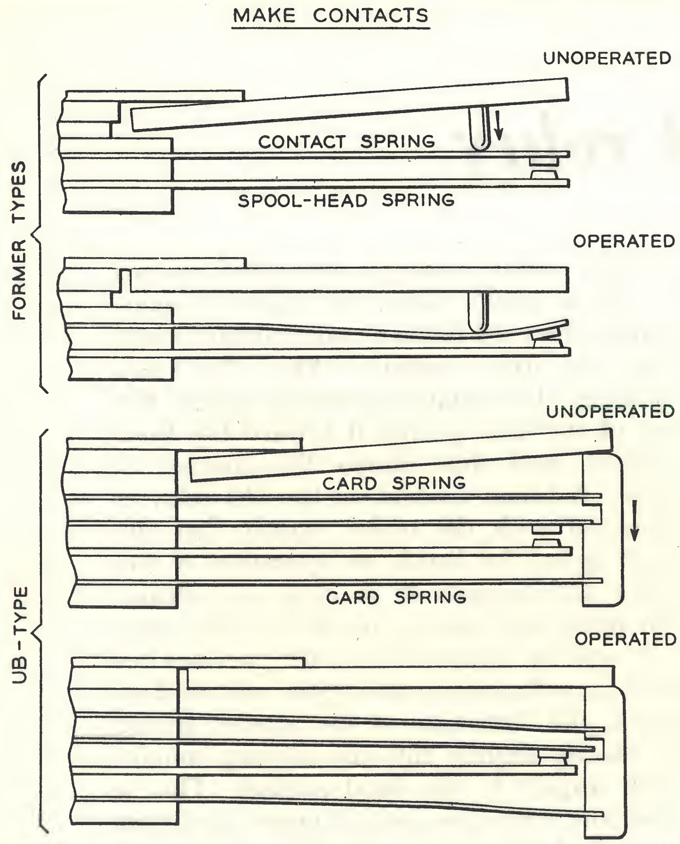



*Fig. 2–Simplified diagram indicating the contact operation of former types of relays, above, and of the UB type, below*

As a result of slight arcing as the contacts open an electrical circuit, there is a transfer of metal from one contact or electrode to the other. This building up and wearing away leaves both contacts roughened. If the opening motion were along a perpendicular to the contacts, this roughening would, ordinarily, have little effect; but with a sliding motion at the contact, small projections on one contact may bind or lock mechanically in a cavity on the other and thus prevent the contacts from opening when they should. In the UB relay, where the contacts are operated without sliding motion, this action is to a large extent avoided.

The likelihood of locking with the UB relay is further decreased because the restoring force is greater and is applied closer to the contact, and because of the impact of the card on the spring when the relay releases. With the contact closed, there is a clearance between the contact spring and the bottom of the slot in the card, and thus when the card hits the spring in opening, it is already moving and has acquired kinetic energy. This energy is available as impact to overcome any tendency of the contacts to stick.

The comparative freedom from dirt troubles obtained with the UB relay is an additional advantage that card operation made possible. The moving springs of double-contact relays are forked, as shown in Figure 3, and each tip of the fork carries a contact–thus providing two contacts for each spring. Should a small particle of dirt hold one contact open, the other contact, because of the independent flexing of the two tips, should still close with substantially the same force. With stud-operated relays, however, the possible length of the tip is limited by the position of the operating stud, indicated in the diagram, and thus the amount of independent flexing of the two tips is similarly limited.

With the UB relay, on the other hand, there is no operating stud, and thus the slot between the tips can be made longer. With the U-type relay, for example, the slot is 0.33 inch, while with the UB it has been made 0.94 inch. Since stiffness varies inversely as the cube of the length, the independence of the tips on the UB relay is twenty-three times greater than that of the U relay. In the Philadelphia accounting center, only half as much trouble from dirt has been experienced with the UB relay as with the U relay.

One of the major advantages of the UB relay is its greater stability of adjustment. With any relay, the pressure of the contacts tends to decrease with wear–wear at the contacts themselves and at certain other critical points in the structure. With the UB relay, however, both the wear and the decrease in pressure with wear are less than with previous relays.

With most types of relays, wear of approximately the same amount takes place at the contacts. Although there is some wear at the card on the UB relay, particularly at the top where the armature pushes it, it is small and does not appreciably affect the contact pressure, which is determined by the pretensioning of the spring.

With the former types of relays, on the

other hand, there is wear of the operating studs as well as of the contacts, and since the pressure at the studs is relatively high, and there is some sliding because of the flexing of the spring, the wear is relatively large. Moreover, with a large spring pileup, there may be several wearing points in series and the wear adds up in its effect on the last spring. For a U-type relay with six make contacts, the loss in travel because of stud wear after 30,000,000 operations is over 6 mils, while for a U relay with six break contacts, it is over 9 mils. Card wear for the UB relay similarly equipped, and for the same number of operations, is negligible. The effect of this wear in requiring readjustment is obvious in Figure 4.

Although this reduced wear of the UB relay is an important factor in decreasing the need for readjustment, a factor of even greater importance is the much smaller rate with which pressure falls off with wear. Force is applied to the contact spring of a UB relay only at or near the free end; the spring is thus a cantilever and the ratio of force to deflection is small—about 0.09 gram per mil of deflection. With previous relays, on the other hand, the spring, once contact is made, acts as a beam—supported by the pileup at one end and by the fixed contact at the other. The operating stud deflects the beam by pressure applied a short distance back of the contact. Under these conditions the ratio of force to deflection is much higher, being about 2 grams per mil of deflection for the U relay. This is illustrated in Figure 5. The shape of the preformed spring of the UB relay is shown at (c)—the end is down about 294 mils below the position it will assume when assembled, indicated at (d). In moving through this 294 mils, a force of 25 grams has been developed, which will be essentially the pressure on the fixed contact when the card releases the spring. When the contacts have worn 10 mils, which is about the maximum permitted, the pressure will still be above 24 grams, since it drops 0.09 gram per mil of deflection.

With the U-type relay, there is no pressure when contact is first made as shown at (a). The pressure is built up to 25 grams by deflecting the spring as shown

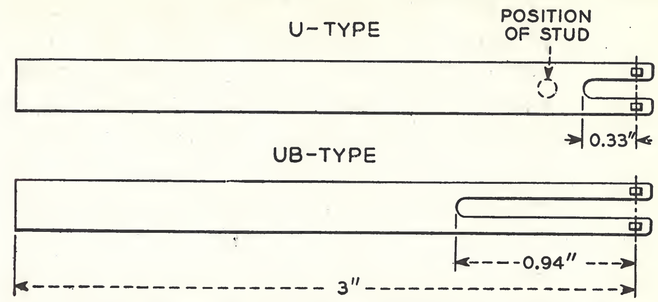



*Fig. 3—The springs of double-contact relays are forked at the end and have a contact on each tine, but the length of the tines is much greater with the UB than with the U relay*

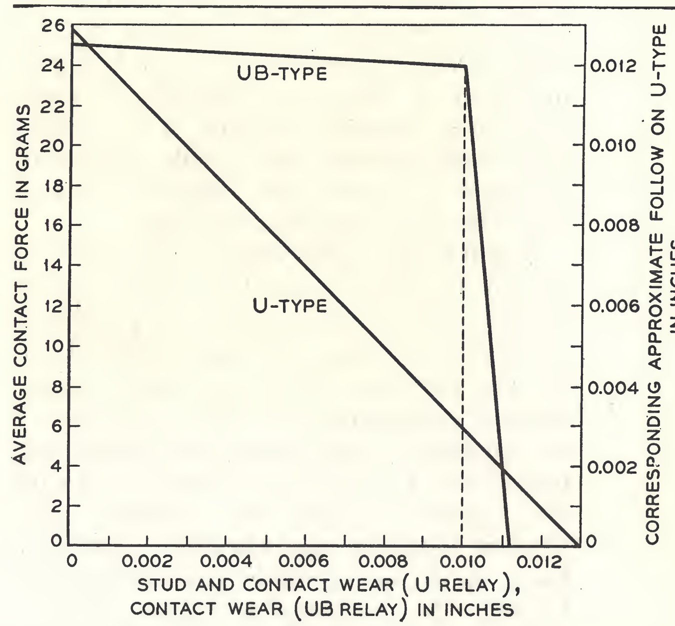



*Fig. 4—Change in contact pressure with wear for "make" contacts of the U relay and of the UB relay*

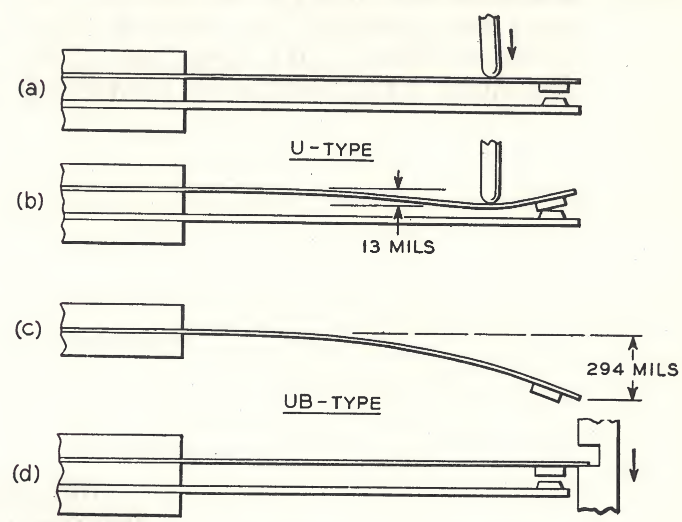



*Fig. 5—Simplified diagram indicating spring actions of "make" contacts of the U relay and the UB relay*

at (b). The much higher ratio of contact pressure to deflection with this beam action—2 grams per mil—requires a deflection of only about 13 mils to build up the pressure to 25 grams. When the combined wear at the stud and contacts is 10 mils, only about 5 grams of pressure will remain. A combined wear of only 2½ mils will reduce the pressure to 20 grams. The drop off of pressure with wear of the UB relay, on the other hand, is so slight as to be negligible, until the contact wear has been great enough to allow this spring to rest against the lower lip of the card in the operated position. This accounts for the sudden drop of the curve for the UB relay in Figure 4. Since it is desirable to maintain good contact pressure, it is obvious that stud-operated types will require adjustment at much more frequent intervals than the card-operated UB type.

A still further advantage of the UB relay is that it requires less hand effort in adjusting. The contact springs are preformed in dies for tension, and thus the hand tensioning after assembly is avoided. An important contribution in this connection is the method of preforming the springs suggested by D. C. Koehler. During the early development stages, the springs were formed between two smooth, curved surfaces shown in the upper part of Figure 6. Considerable variation in tension was encountered, however, because of differences in the spring-back of the various springs when removed from the forming tool. This effect was minimized by using two sharp bends, as shown in the lower part of the illustration. The bends are so located that the resulting shape of the spring approximates that of the elastic curve for a cantilever spring. This was done so that the spring will be reasonably straight and parallel with the mating spring when it is held in position in the assembled relay. The contact force distribution of springs formed by the two methods is shown at the right of the illustration.

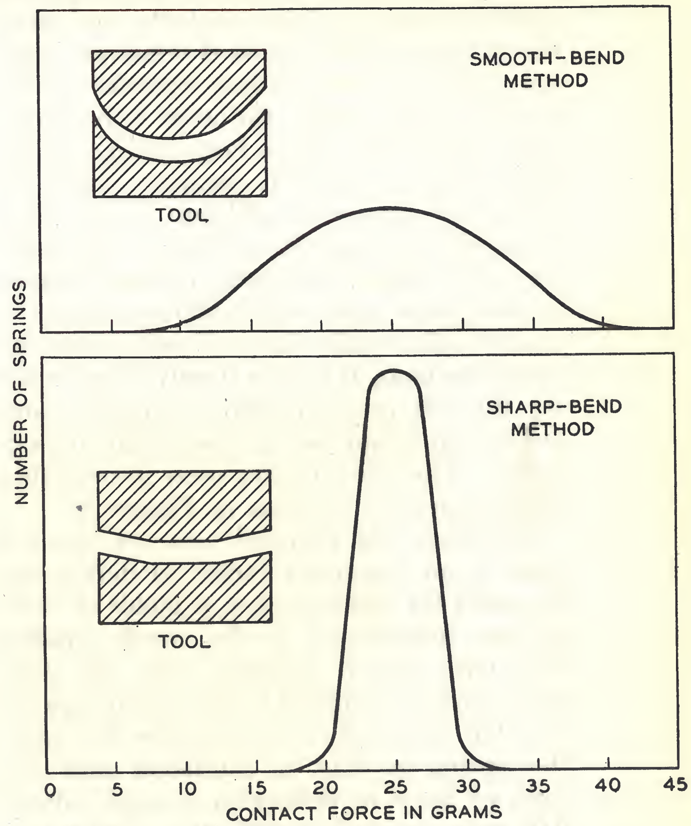


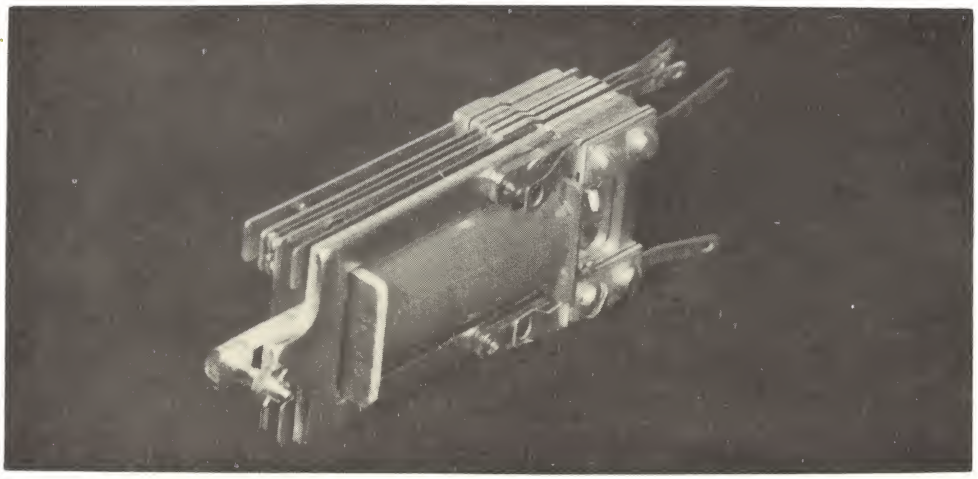

*Fig. 6—Frequency distribution of contact force with early and final methods employed for preforming springs of UB relay*

BIBLIOGRAPHY
Bell System Publications

H. M. Knapp
BLR 10-49

Issued by:
Telephone Systems Training Section
11-11-49

# THE Y-TYPE RELAY



In many of their applications in the Bell System, relays are required to act as rapidly as possible. They should operate promptly when voltage is applied to them, and release promptly when the circuit to their winding is opened. There are numerous applications, however, where it is necessary for the relay to remain operated for an interval after the circuit to its winding is opened, and this release interval is often specified within very close limits. Precise behaviour of this kind is not easy to secure; only careful design and accurate control of manufacture make it possible. Relays that are most economical for general uses will not meet the very exacting requirements laid down to secure a precise slow-release period. When the general utility U-type relay was developed, it seemed desirable, therefore, to develop at the same time a slow-release relay that so far as possible would use the same parts, manufacturing tools, and processes. The result was the Y-type relay, which is shown in the photograph at the head of this article.

The need for dependable slow-release relays can be well illustrated by one of their applications in the panel systems. A group of relays in the sender records each digit dialed, and it is necessary to switch the dialing circuit from one group to the next after each digit of the called number. As the dial returns after having been pulled around to one of the digits, it opens and closes the circuit in rapid succession to indicate the digit dialed. Thus in dialing 2 the circuit will be opened and closed twice, and in dialing 4 the circuit will be opened and closed four times. Immediately after its return, the dial is pulled around for the next digit, and during this short interval between digits the circuit must be switched to the next group of recording relays. This is accomplished through a slow-release relay that does not release during the short open periods of each digit, but does in the slightly longer period between digits. It must do this regardless of the commercial range in dial speeds, of voltages and line variations, and in the speed with which the dial is pulled around. In the latest type sender the actual requirements for the Y-type relay are that it shall release in not less than 0.080 second nor in more than 0.120 second. The ordinary relay, however, releases in from 0.005 to 0.015 second. In designing a slow-release relay, therefore, there are two objectives sought: first to provide the slow-release action, and second to provide for an accurately controlled release time.

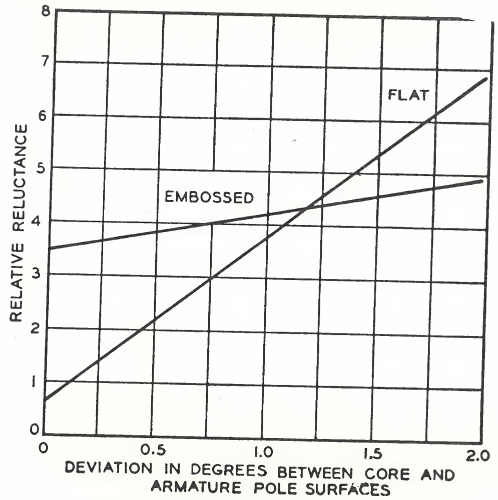



Fig. 4 - Variations in reluctance of relay with angle at which armature meets the core for both flat and embossed pole pieces.

The effects of these structural differences on the reluctance are shown in Figure 4 for relays with flat surfaces and for those with the spherical and cylindrical surfaces of the Y-type relay. With perfect alignment the reluctance of the flat surfaces is very low, but it increases rapidly with an increase in the angle between core and armature. The reluctance of the rounded surfaces is much higher for perfect alignment, but it increases only very slightly as the deviation in the alignment increases, and thus gives the constancy of reluctance particularly desirable for a slow-release relay.

The reasons for this are obvious. With a flat surface in perfect alignment - zero angular deviation - the contact is spread over the entire surface, and the reluctance as a result is very low. When the armature meets the pole face at an angle, however, there is a wedge-shaped air gap formed, and the greater the angle of contact, the greater will be the width - and thus the reluctance - of this gap. With the spherical or cylindrical surfaces, the contact is always in a point or line with a narrow air gap at the sides regardless of the angle with which the armature meets the contacting surfaces. The reluctance of such a contact is higher than that of two flat surfaces where the angle is small, but remains essentially constant, while that of the flat surfaces increases steadily as the angle widens.

A protective coating is plated on the magnetic structure to prevent corrosion of the iron, but since this coating is non-magnetic, it introduces what is effectively an air gap in the magnetic circuit. Variations in the thickness of this plated coat would affect the release time by varying the reluctance of the magnetic circuit. The closeness with which the release time must be held with the Y-type relay, therefore, requires that the thickness of the plating be held within very close limits; the actual range is from 0.0003 to 0.0006 inch. Chromium is used for the outer plating to provide a very hard surface to resist wear at points of contact between the armature and core.

As a result of the consistency in reluctance obtained by these various means, the variations in release time are considerably reduced. For the Y-type relay the variations in release times are shown by the shaded area of Figure 5. For a corresponding relay with flat surfaces, the release time might fall anywhere between the curves A and B. With rounded surfaces the variation in release time is thus cut from one-half to one-third of what it would be with flat surfaces.

So uniform are the characteristics of the Y-type relay that the release time can be closely predicted from the value of the current necessary to hold the relay operated. Heretofore it has been necessary to check the operation of slow-release relays by actually measuring the release times, which is a rather slow and expensive procedure. With the Y-type relay such measurements are unnecessary; it is sufficient to measure the holding current; because of the close correspondence between holding current and release time.

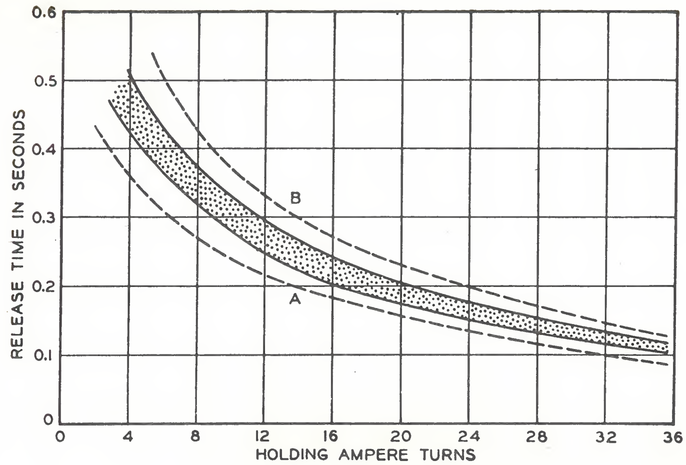



Fig. 5 - Variations in release times for flat and rounded pole surfaces. Shaded area shows variations for Y-type relays.

Except for these differences, the Y-type relay is the same as the U-type, and to the casual glance one could not be told from the other. Moreover, the copper sleeves designed for the Y-type relay may be employed with the U-type to secure somewhat slower release, although the long release obtained with the Y-type relay cannot be secured with the U-type, nor can the accuracy of release time for the relay be maintained.

As the U-type relay is intended to be the general utility relay of the future, replacing ultimately the E and R types, so the Y-type will be the slow-release relay of the future - replacing the 149, 162, 178, and T types.

Western Electric Co., Inc.
Hawthorne Works
Personnel Service Branch
Training Department

Information Pamphlet 2.1-106
For Training Purposes Only

# MERCURY CONTACT RELAYS

## Development and Use

Relay contacts between solid metal surfaces tend to give trouble in a number of ways. They wear down, get dirty, stick by locking or welding, and chatter. It has long been recognized that all of these difficulties might be avoided by using mercury contact surfaces instead of solid metal. However, most designs of relays of mercury have tended to be slow in operation, ordinarily being based on the moving of a fairly large quantity of mercury by the force of gravity.

The Bell Telephone Laboratories have developed the techniques for maintaining solid metal contact surfaces continuously wet with mercury by means of a capillary connection to a mercury reservoir below the contacts. This minimizes the amount of mercury which has to be put in motion for operation and permits the moving contacts to be carried by a light armature capable of high speeds.

## Description of Relays

Two relays, the 275 and 276, have been developed. Each consists of a 218-A mercury switch surrounded by a solenoidal coil and assembled in a metal "vacuum tube" shell equipped with an octal "vacuum tube" base.

In addition, the 276 type relay is provided with a small magnet for biasing the armature. A cross-sectional view of a 276 type relay is shown in Figure 1.

The 218-A mercury contact switch consists essentially of an armature and two sets of contacts enclosed in a glass tube filled with hydrogen gas under pressure. The armature is a small piece of permalloy attached to a supporting spring and equipped with a contact arm.

The armature is pretensioned so that the armature contact normally rests against the back contacts, which are supported on non-magnetic material. The front contacts are attached to the upper pole pieces which, together with the front contact leads and the lower pole piece, all made of magnetic material, complete the magnetic circuit within the switch.

On the bottom of the glass tube is a small amount of mercury which, by capillary action over the armature capillary, keeps the contacts coated with mercury.

## Method of Operation

When an operating current is applied to the coil of a 275 type relay the magnetic flux set up by the coil magnetizes the armature and pole pieces in such a manner as to cause the armature to be attracted to the upper pole pieces.

As the armature and back contacts separate, a film of mercury is formed between them which becomes narrower in cross section and finally breaks at two points, allowing a small drop of mercury to fall out. This opens the circuit which had been carried through the armature and back contacts. As the armature reaches the front contacts a fluid contact is re-established which electrically bridges any mechanical chatter. A similar condition takes place when the relay is released.

Similar action takes place on the 276 type relay except that the flux from the biasing magnet (permanent magnet), adjusted to the required value at the time of manufacture, will permit the relay to operate or release within close limits.

The mercury layer also protects the underlying solid metals from electrical erosion and also reduces the mechanical wear.

These relays are preferably mounted in a vertical position but may be mounted as much as 30° from the vertical position without affecting their characteristics.

### Performance Characteristics of Mercury Sealed-Glass Relays

| | |
|---|---|
| Magnetic Material | Permalloy |
| Contact Material | Platinum bathed in mercury |
| Gaseous Environment | Hydrogen at 250 pounds pressure |
| Nominal Power - Operate | .18 watt |
| Nominal Power - Release | .10 watt |
| Time to Operate on 48 v. d-c | .0047 sec. (approx.) to make front contact<br>.0051 sec. (approx.) to break back contact |
| Time to Release on Open Circuit | .0039 sec. (approx.) to break front contact<br>.0035 sec. (approx.) to make back contact |
| Current Rating | 5 amps. (20 watts) |
| Life Expectancy with Adequate Contact Protection | $10^9$ operations |

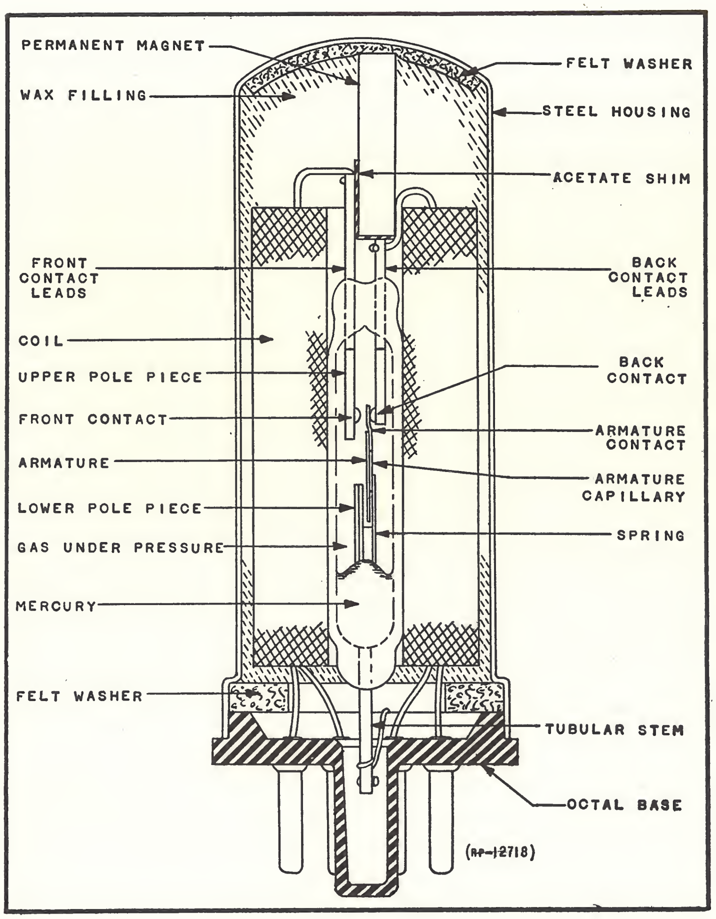



FIG. 1

276 TYPE RELAY

Western Electric Co., Inc.
Hawthorne Works
Industrial Relations Branch
Training Department

Information Pamphlet 2.1-115B

# CONVENTIONS

The purpose of this publication is to supply a ready reference to the conventions used by the Bell Telephone Laboratories in preparation of Circuit Schematics.

For reference purposes only, and will not be kept up to date.

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Installers Handbook No. 0

Distributed by:
Telephone Systems Training Section.

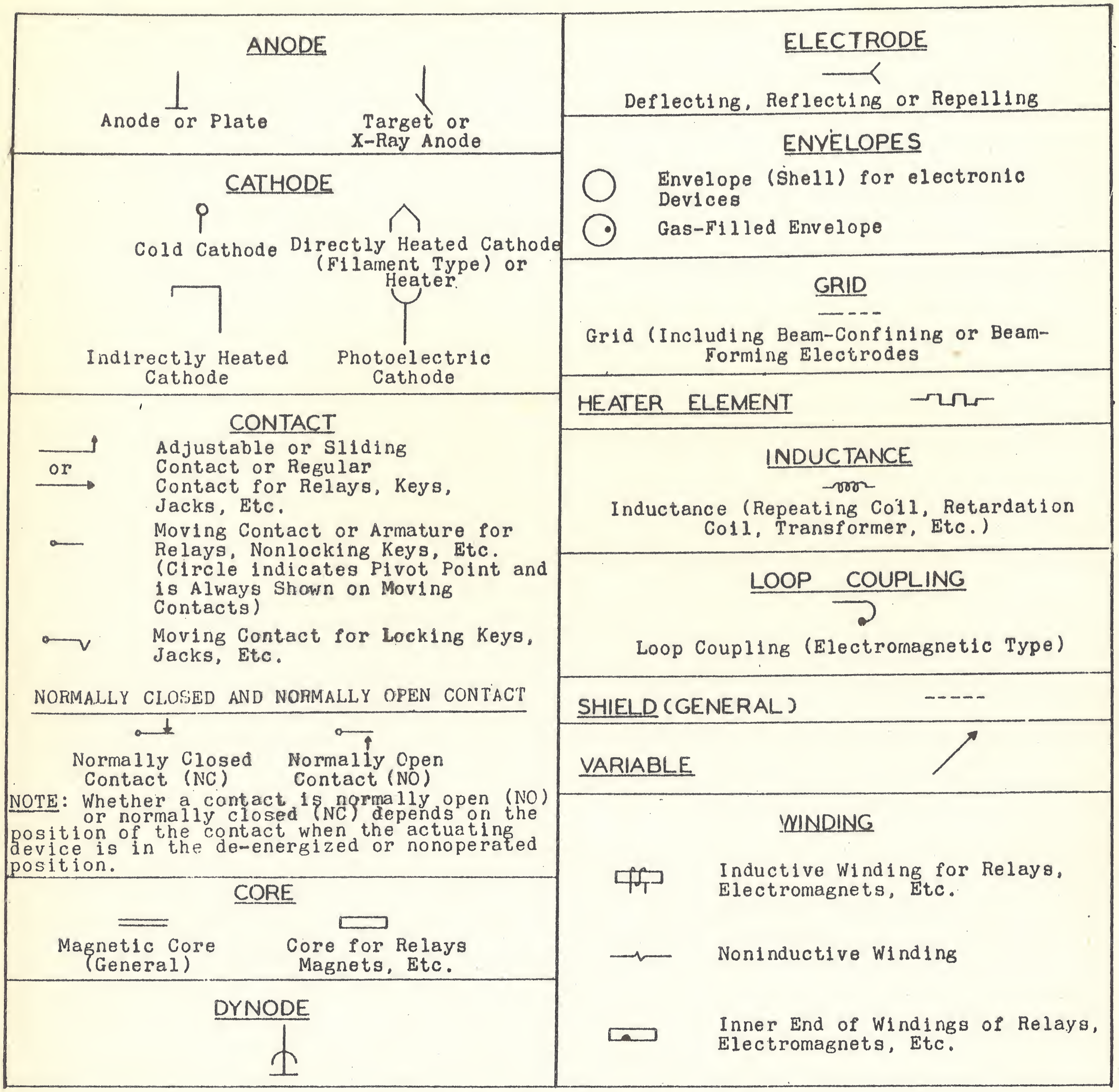
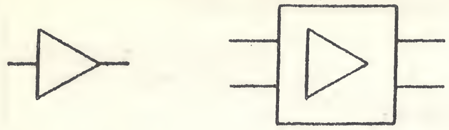



FIG. 5 SYMBOL COMPONENTS (PAR. 7.21)

SYMBOL COMPONENTS APPLIED TO PRIMARY APPARATUS CONVENTIONS

AMPLIFIER



Single Line Diagrams

Where More Leads are Shown

AMMETER (SEE INSTRUMENTS)

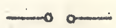
AMPERE-HOUR METER (SEE INSTRUMENTS)

ANTENNA

Aerial

Counterpoise

Loop

ARRESTOR 

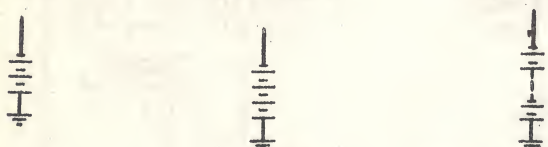
AUTOTRANSFORMER (SEE INDUCTORS)

BATTERIES

Dry Cell

CEMF Cells

24 Volts



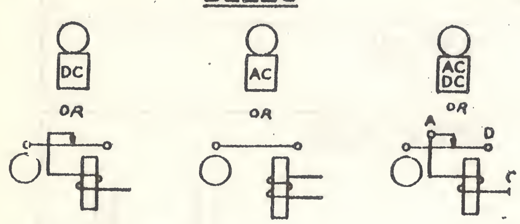
38 Volts

48 Volts

Over 48 Volts

NOTE: The above indicates positive side grounded. To indicate negative side grounded, interchange long and short lines.

BELLS



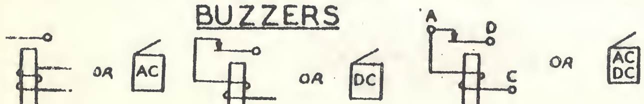

A-C

D-C

AC-DC

BINDING POSTS 


BUZZERS




A-C

D-C

AC-DC

CAPACITORS (SEE CONDENSERS AND CAPACITORS)

CIRCUIT BREAKER

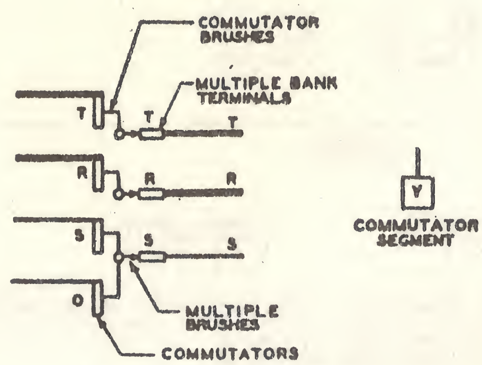
CLOCK (SEE ELECTRIC CLOCK)

CLUTCH MAGNETS


H.S. - High Speed
L.S. - Low Speed

COILS (SEE SPECIFIC TYPE)

COMMUTATOR




Panel System Type

CONDENSERS AND CAPACITORS

(OLD)

(NEW)

Fixed

Fixed

Fixed


Variable

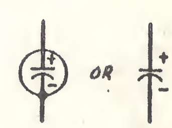
Variable


Trimmer Type

Variable or Adjustable

Variable (Trimmer Type)

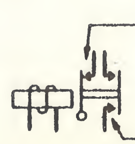
Split Stator




Electrolytic

CONNECTING BLOCK (SEE TERMINALS)

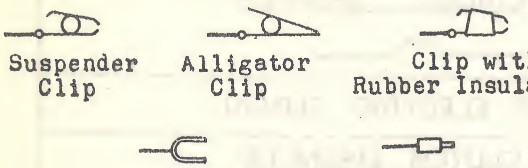
CONTACTOR



NORMALLY CLOSED MAIN CONTACTS

INTERLOCK CONTACTS

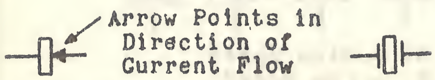
## CORD TIPS



Suspender Clip — Alligator Clip — Clip with Rubber Insulation

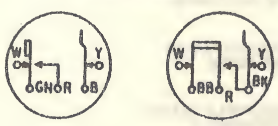
Spade Tip — Plug Tip

## CRYSTALS




Detector — Piezo-electric

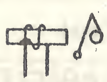
## DIALS




## DROPS

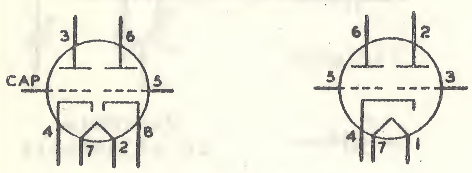
Manually Restored — Electrically Restored

## ELECTRIC CLOCK

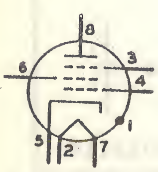


## ELECTROMAGNET

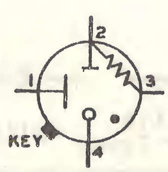
## ELECTRON TUBES



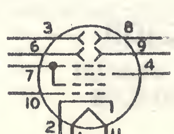

Twin-triode




Pentode

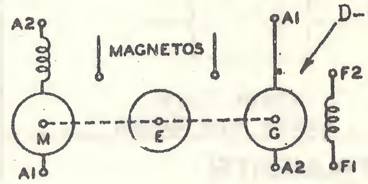



Cold Cathode




Cathode-ray

## ENGINE-GENERATOR SET




Charging Generator D-C Shunt Type

With Starting Motor and Magnetos

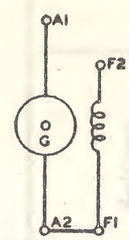
## FREQUENCY METER (SEE INSTRUMENTS)

## FUSES

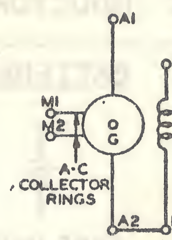
Plain Type — Alarm Type — Alarm Type on Bus Bar — Alarm Type on Protector Mounting — Safety Type

## GALVANOMETER (SEE INSTRUMENTS)

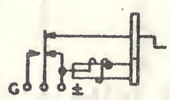
## GENERATOR



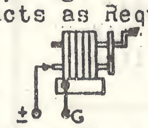

Charging Generator D-C Shunt Type



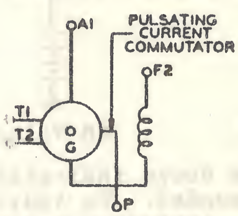

Ringing and Coin Control Generator




Springs and Contacts as Required

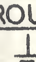



Hand Type



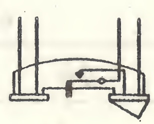

Ringing Generator with Pulsating Current Commutator

## GROUND

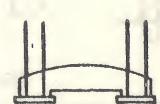


## HAND SETS

3 Conductor



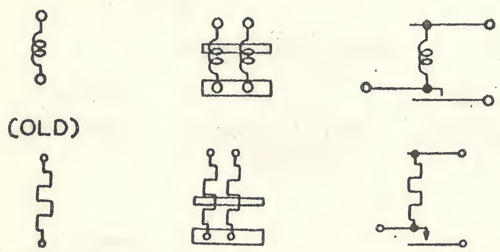
4 Conductor with Transmitter Cut-Off Key



4 Conductor

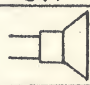
## HEAD SET (SEE RECEIVERS)

### HEAT COILS



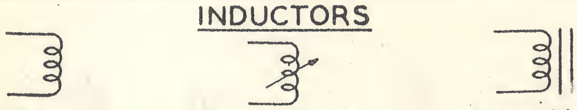

Plain | Alarm Type on Bus Bar | Alarm Type on Protector Mounting

### HORN OR HOWLER

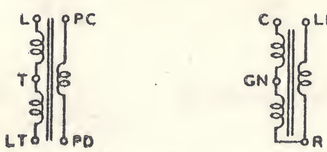


## INDUCTION COIL (SEE INDUCTORS)

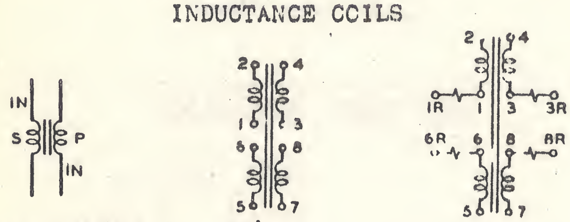
### INDUCTORS



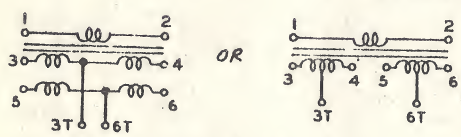
Fixed | Variable or Adjustable | Magnetic Core



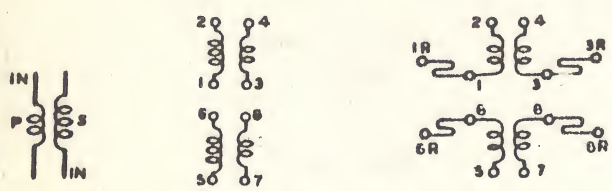

INDUCTANCE COILS



Relay Spool Type | Regular Type | With Non-Inductive Windings



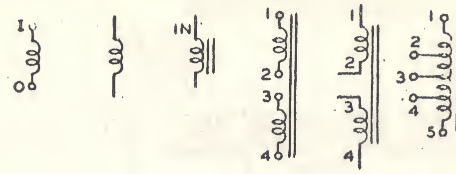

Hybrid Type

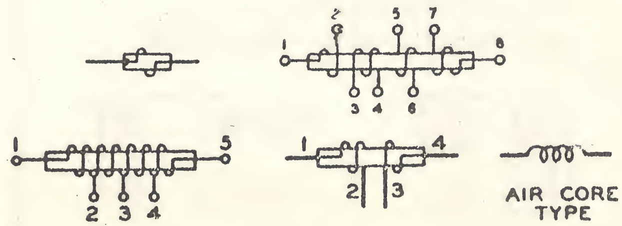


Relay Spool Type | Windings in Unequal Ratio | With Non-Inductive Windings and with Inductive Windings in Equal Ratio

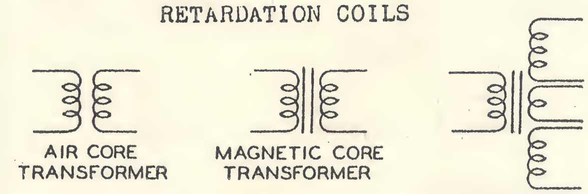
REPEATING COILS

## INDUCTORS (CONT'D)

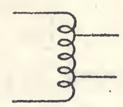




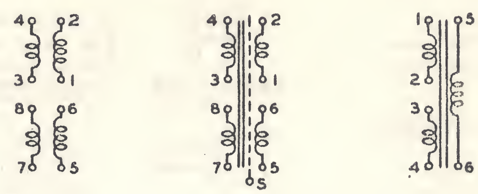

RETARDATION COILS



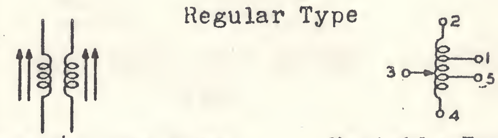
AIR CORE TRANSFORMER | MAGNETIC CORE TRANSFORMER | MAGNETIC CORE MULTI-WINDING TRANSFORMER



AUTO TRANSFORMER



Regular Type

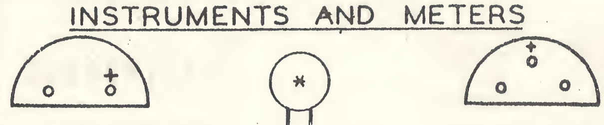


Variable Core Type | Variable Tap Type

TRANSFORMERS

(Terminals and designations are shown only when terminals require identification)

## INSTRUMENTS AND METERS



Non-Differential Milliammeter | Differential Milliammeter

* Show abbreviations to identify the specific type of instrument or meter. For example:

A - Ammeter
AH - Ampere-hour
F - Frequency
G - Galvanometer
MA - Milliammeter
PF - Power Factor
TT - Total Time
V - Voltmeter
VA - Volt-ammeter
VO - Volt-ohm
W - Watt
WH - Watt-hour
A - Microammeter

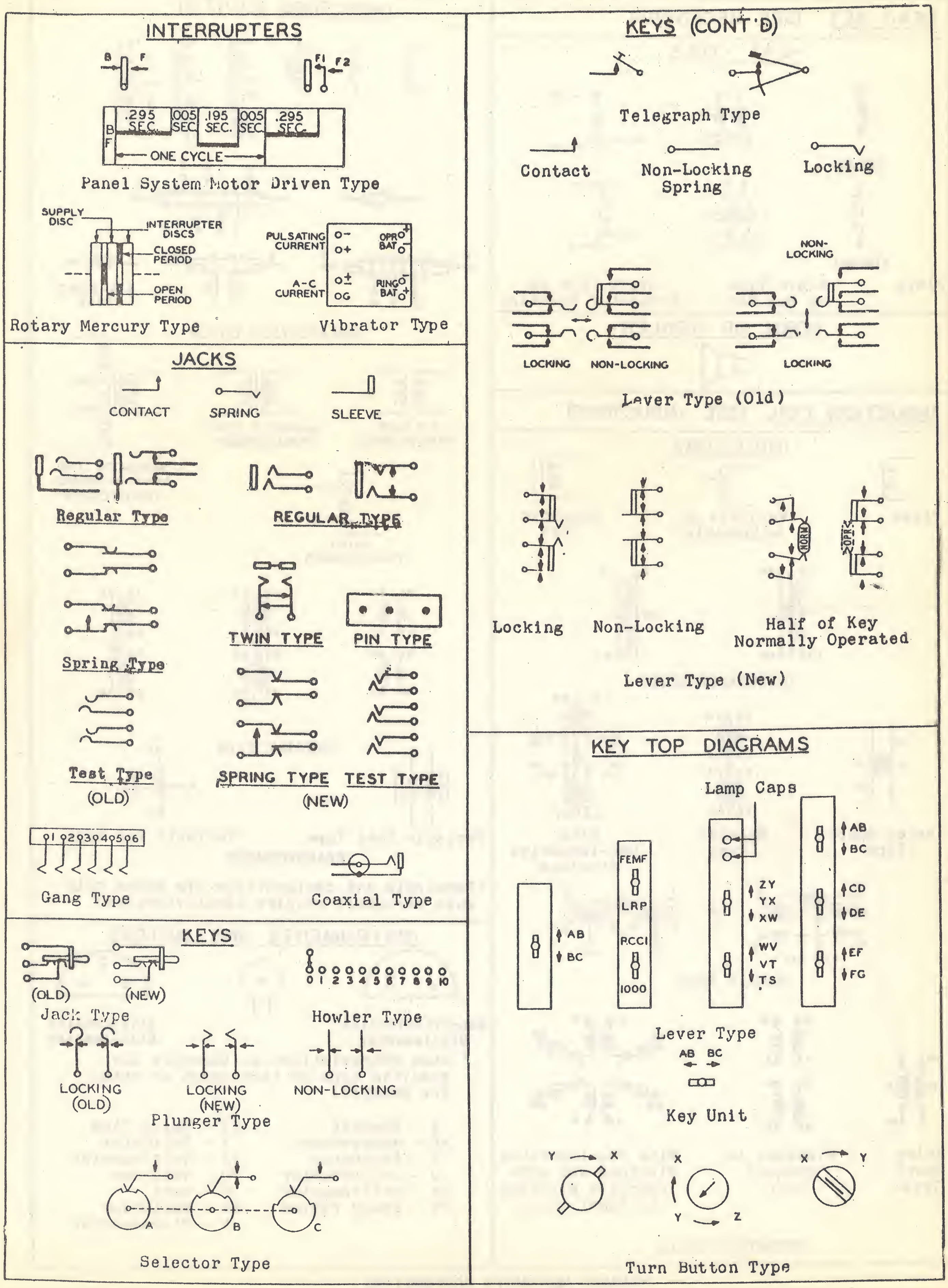
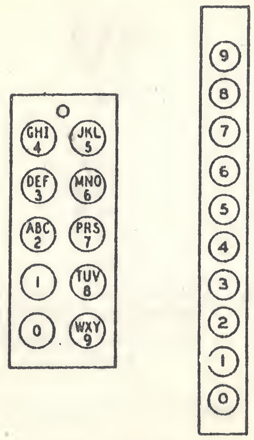


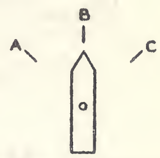

FIG. 10 PRIMARY APPARATUS CONVENTIONS

## KEY TOP DIAGRAMS (CONT'D)



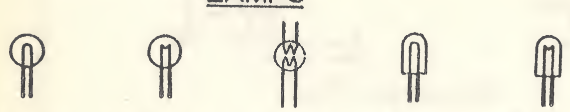

Push Button Type

NOTE: Show designations within key tops only when engraved.




Selector Switch Type

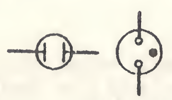
## LAMPS



Carbon Filament | Metallic Filament | Double Filament | Carbon Filament | Metallic Filament

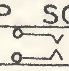
Ballast or Resistance Type | Switchboard Type

(OLD)
Illuminating Type

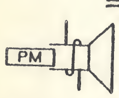


(NEW)
Glow Type

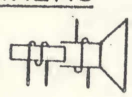
## LAMP SOCKET



## LOUD SPEAKERS

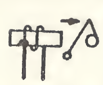



Permanent Magnet Type



Electromagnetic Moving Coil Type

## MESSAGE REGISTER



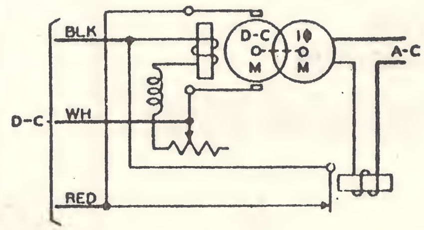
## METERS (SEE INSTRUMENTS)

## MICROPHONES (SEE TRANSMITTERS)

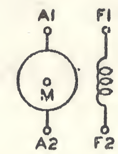
## MILLIAMMETER (SEE INSTRUMENTS)

## MICROAMMETER (SEE INSTRUMENTS)

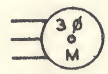
## MOTORS



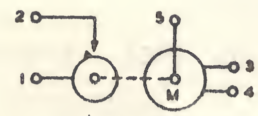

Duplex Type




D-C Shunt Type

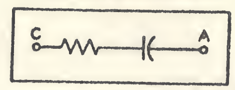



A-C 3 Ø Induction Type




Power Failure Control Type

## NETWORKS



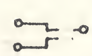

Typical


When Used as Contact Protection

## PIEZO-ELECTRIC (SEE CRYSTALS)

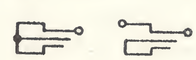
## PLUGS

1 Conductor

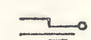


2 Conductor

3 Conductor



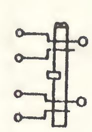
Make Busy



Dummy

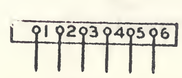
Old

New Service Type



Twin

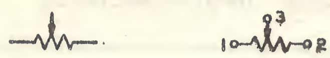
Test




Gang

Coaxial

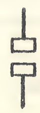
## POTENTIOMETERS



## POWER FACTOR METER
(SEE INSTRUMENTS)

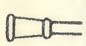
## PROTECTOR AND PROTECTOR BLOCKS


Protector


Protector Block

## PUNCHING (SEE TERMINALS)

## RECEIVERS


Hand Type


Receiver Unit

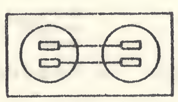

Single Headset


Double Headset

## RECEPTACLES



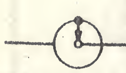
Old

New

## RECTIFIERS (SEE VARISTORS)

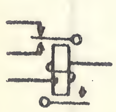
## REGULATOR

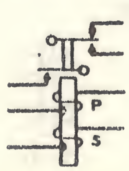

Normally Closed

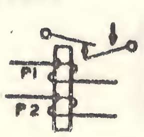

Normally Open

Centrifugal Type Speed Regulator

## RELAYS

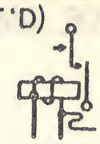

Single Wound


Double Wound


Parallel Wound Normally Operated

## RELAYS (CONT'D)


Old


Old

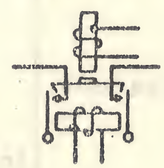

New

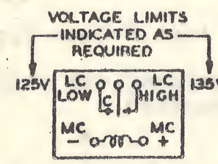
No Permanent Connection Between Inductive and Non-Inductive Windings


New

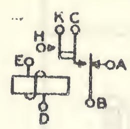
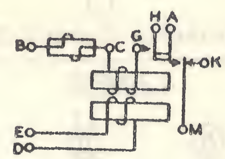
Permanent Connection Between Inductive and Non-Inductive Windings

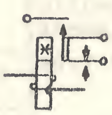
Relays With Non-Inductive Windings


Mechanically Locking Electrically Releasing



Voltage Type



Telegraph Type

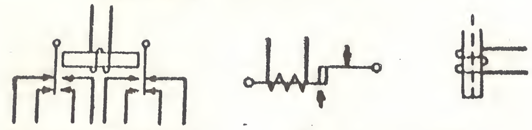


Relays With Particular Operating Features

*Show abbreviations as follows for specific operating features if required. On polarized relays used in telegraph circuits, the designations "S" and "M" indicate the "spacing" and "marking" contacts, respectively.

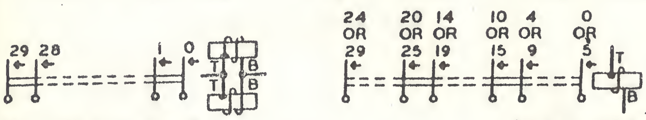
- AC - Alternating current
- D - Differential
- DB - Double-biased - biased in both directions
- DP - Dashpot
- EP - Electrically polarized
- FO - Fast operate
- FR - Fast release
- MG - Marginal
- NB - No bias
- NR - Nonreactance
- P - Magnetically polarized using biasing spring or having magnetic bias
- SA - Slow acting
- SO - Slow operate
- SR - Slow release
- TS - Two-step

## RELAYS (CONT'D)



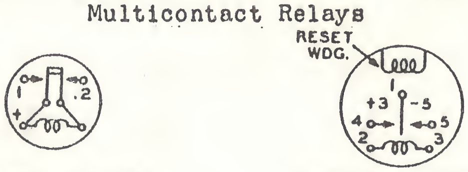
Double Contact Type | Old | Old


Parallel Wound Normally Operated | New Thermostat Type Relay | New Solenoid Type Relay

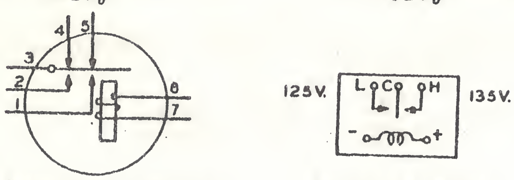



Non-Split Type | Split Type

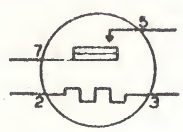
Multicontact Relays



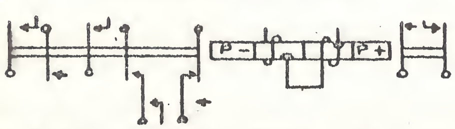

Ammeter Type Relay | Sensitrol Type Relay



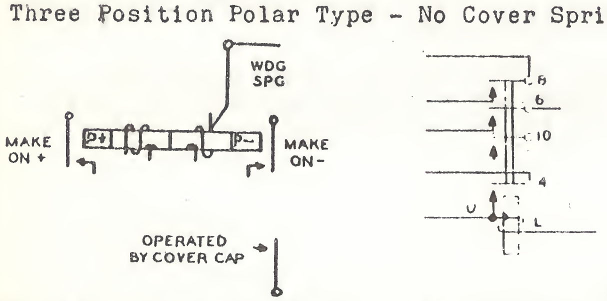

Mercury Contact Type Relay | Voltage Type Relay



Thermal Delay Relay



Three Position Polar Type - No Cover Spring



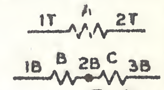

Three Position Polar Type With Cover Spring | Wire Spring Type Relay

## REPEATING COILS
(SEE INDUCTORS)

## RESISTORS

With One Winding

With Two Windings and Having One Terminal Common to Both Windings




Relay Spool Type

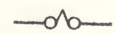
## RETARDATION COIL
(SEE INDUCTORS)

## RHEOSTAT

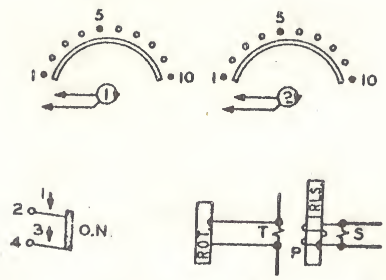
Two Wire

Three Wire

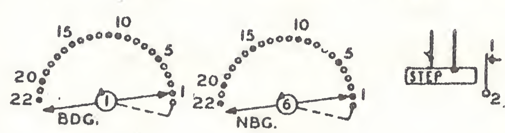
## RINGER



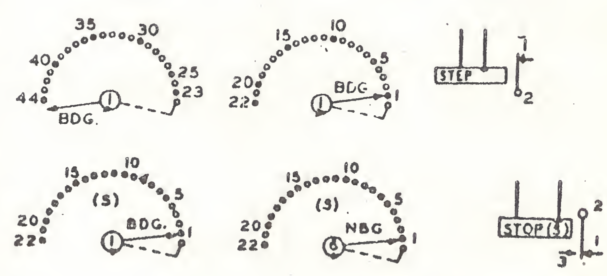
## SELECTORS




10 - Terminal Rotary - Type Selector



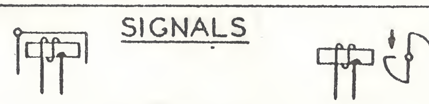

22 - Terminal Rotary - Type Selector



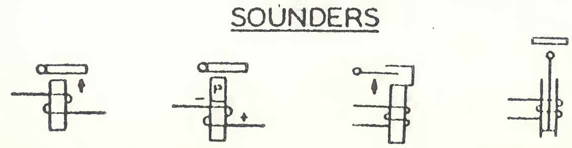

44 - Terminal Rotary - Type Selector

## SEQUENCE SWITCH (SEE SWITCHES)

## SIGNALS

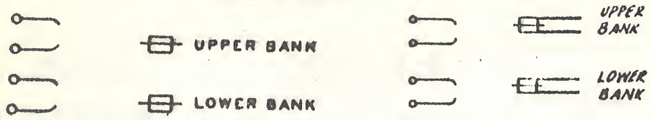


## SOUNDERS



Neutral | Polarized | Telegraph | Chime, Tone, Bar, Etc.

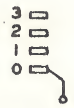
## SWITCHES



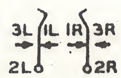

Wipers Banks Wipers Banks

Old New

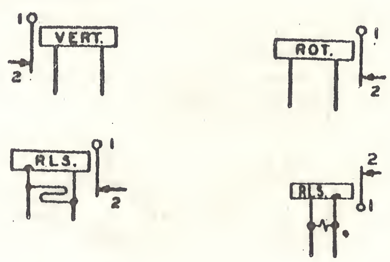
Wipers and Banks




Vertical Commutator and Wiper

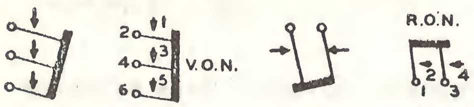



Normal Post Springs




Old New

Magnets




Old New Old New

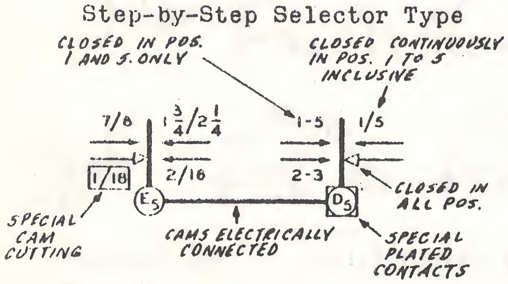
V.O.N. Springs R.O.N. Springs

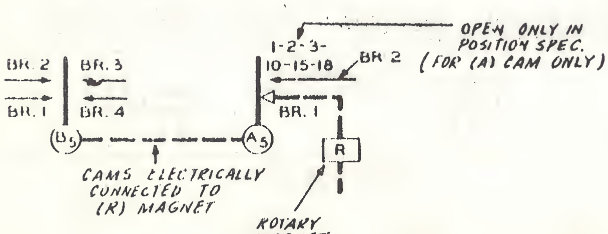
11th Rotary Step Springs

Old New

Test Jacks

Step-by-Step Selector Type




Sequence Switch Type

## SWITCHES (CONT'D)

Cover or Door Type

S.P.S.T. S.P.D.T. D.P.S.T. D.P.D.T.

Old

Snap, Rotary, Tumbler or Toggle Type


S.P.S.T. D.P.D.T.

Convention for Blade of Switch
May be Added if Desired

Old

Knife Type

S.P.S.T. D.P.D.T.

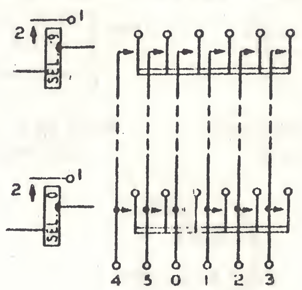
Old

Strap or Table Type

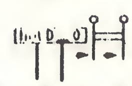
S.P.S.T. S.P.D.T. D.P.S.T. D.P.D.T.

New

Knife, Rotary, Snap, Toggle or Tumbler Type




NOTES:



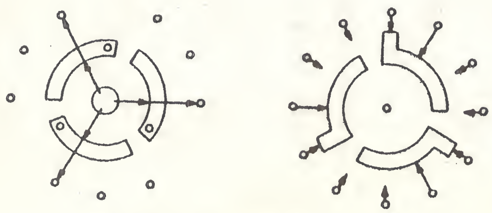
A. SEL magnets may be placed on right or left of contacts as best suits wiring condition.

B. Contacts on SEL or HOLD magnets may be shown at either end of magnet core to suit schematic conditions.

C. HOLD magnets may be shown under SEL magnets where wiring from contact terminals is run vertically.

Crossbar Selector Type

## SWITCHES (CONT'D)



Selector Type

## SWITCHHOOK

## TERMINALS



Apparatus Terminal

Cross-Connecting Punching

Terminal Strip Punching

| | | |
|---|---|---|
| 01 | 60 | 110 |
| 02 | 70 | 120 |
| 03 | 80 | 130 |
| 04 | 90 | 140 |
| 05 | 100 | 150 |

Jack Type

Terminal Strip

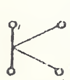
## TEST POINT


## THERMISTORS

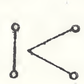
Directly Heated

Indirectly Heated

## THERMOCOUPLES



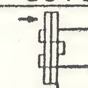
Directly Heated



Indirectly Heated

## THERMO - CUTOUT

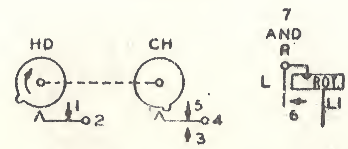
External Heater Unit



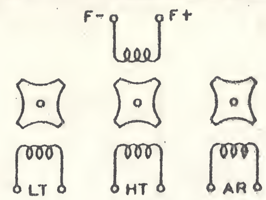
Integral Heater Unit

Self-Heated Unit

## TIMERS



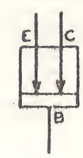

## TONE ALTERNATOR



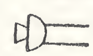

## TOTAL TIME METER
(SEE INSTRUMENTS)

## TRANSFORMER (SEE INDUCTORS)

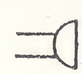
## TRANSISTOR




## TRANSMITTERS



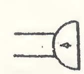
Transmitters



SINGLE-BUTTON

DOUBLE-BUTTON

CONDENSER



VELOCITY

CRYSTAL

MOVING COIL

Microphones

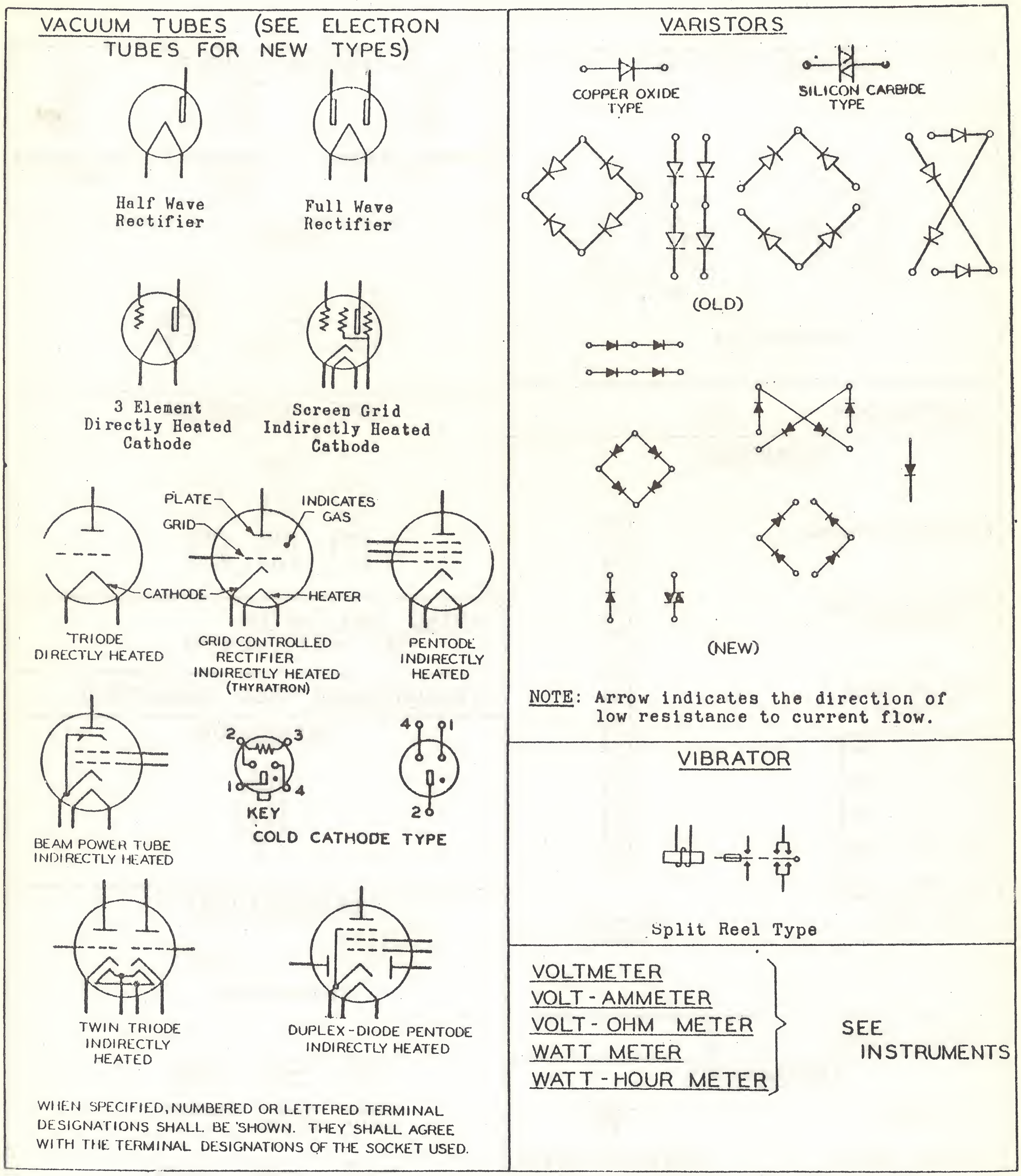
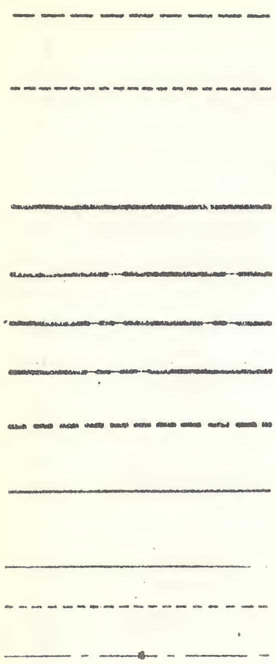


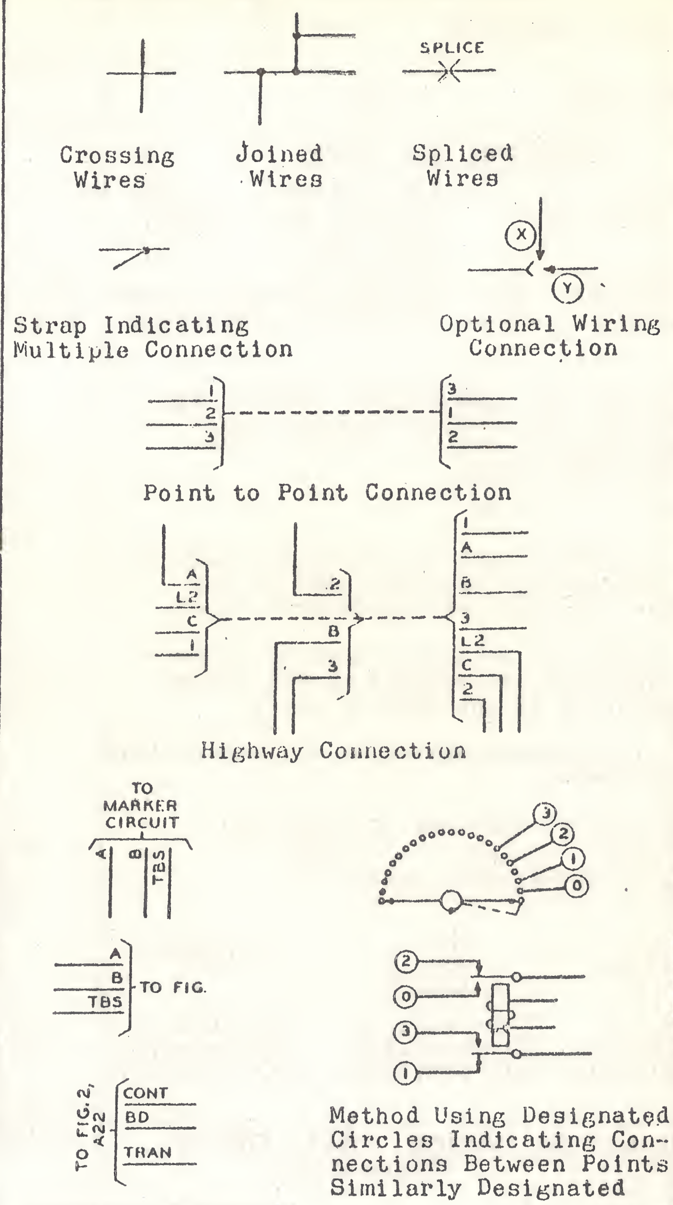

FIG. 16 PRIMARY APPARATUS CONVENTIONS (CONT'D)

## LINE CONVENTIONS



- Jumper
- Leads for Showing the Details of One Circuit on Another Circuit (Dotted Leads)
- Talking, Transmission, Bus Bar, Charge, and Discharge
- Fundamental Circuit
- Off-Normal Ground
- Off-Normal Battery
- Sequence Switch Rotary Magnetic Feed
- Signal and Power Control
- Apparatus
- Mechanical Connections
- Division Lines

## METHODS OF SHOWING LEADS




Crossing Wires

Joined Wires

Spliced Wires

Strap Indicating Multiple Connection

Optional Wiring Connection

Point to Point Connection

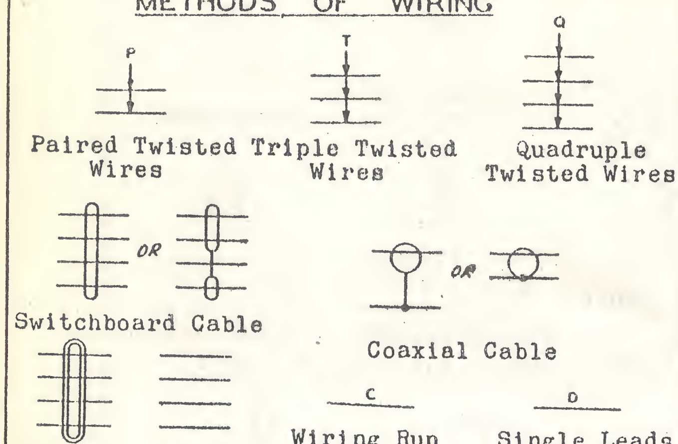
Highway Connection

COORDINATED BRACKET

Lead Connections to Another Figure or Drawing

Method Using Designated Circles Indicating Connections Between Points Similarly Designated

## METHODS OF WIRING




Paired Twisted Wires

Triple Twisted Wires

Quadruple Twisted Wires

Switchboard Cable

Coaxial Cable

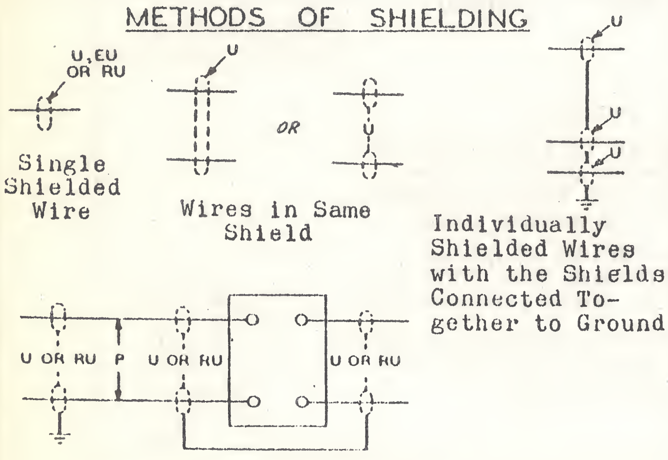
Duplex Cable

Local Cable

Wiring Run in Separate Switchboard Cable

Single Leads Run From Terminal to Terminal

## METHODS OF SHIELDING



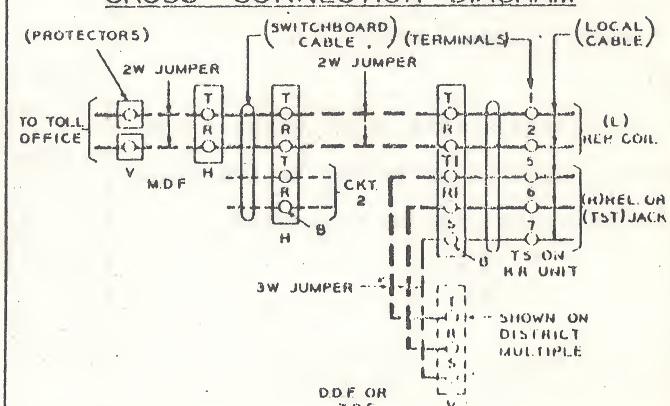

Single Shielded Wire

Wires in Same Shield

Individually Shielded Wires with the Shields Connected Together to Ground

Typical Paired and Shielded Wiring

## CROSS CONNECTION DIAGRAM




(Showing Typical Wiring and Terminal Conventions)

PRIMARY WIRING CONVENTIONS

## ANTENNA - GENERAL

## ATTENUATOR

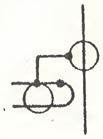
## COUPLING BY LOOP

Coupling By Loop to Space

Coupling By Loop to Guided Transmission Path

Application:

Coupling By Loop from Coaxial to Circular Waveguide with D-C Grounds Connected



## COUPLING BY APERTURE WITH AN OPENING OF LESS THAN FULL WAVEGUIDE SIZE

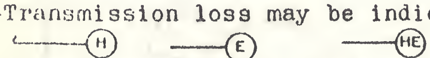
Designate E, H, or HE.

(1) "E" indicates that the physical plane of the aperture is perpendicular to the transverse component of the major E lines.

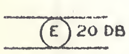
(2) "H" indicates that the physical plane of the aperture is parallel to the transverse component of the major E lines.

(3) "HE" indicates coupling by all other kinds of apertures.

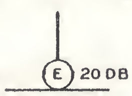
(4) Transmission loss may be indicated.



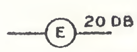

Coupling by aperture to space.




Four Ends of Transmission Path Available




Three Ends of Transmission Path Available




Two Ends of Transmission Path Available

## COUPLING BY PROBE (SEE OPEN)

Coupling By Probe to Space

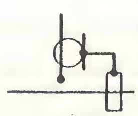


Coupling By Probe to a Guided Transmission Path



Application:

Coupling By Probe from Coaxial To Rectangular Waveguide with Grounds Connected



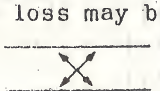
## DIRECTIONAL COUPLER

General

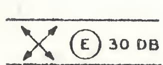
(1) Arrows indicate direction of power flow.

(2) Number of coupling paths may be indicated.

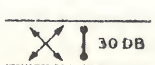
(3) Transmission loss may be indicated.



Aperture Coupling, Designate E, H or HE



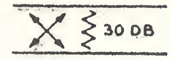

Coaxial Loop Coupling, 30-db Attenuation




## DIRECTIONAL COUPLER (CONT'D)

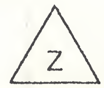
Coaxial Probe Coupling, 30-db Attenuation

Resistance Coupling

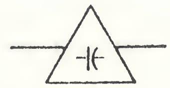



## DISCONTINUITY

To be drawn for a component that exhibits the properties of one of the kinds of circuit elements throughout the frequency range of interest.



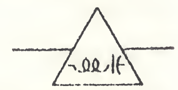

Equivalent Series Element-General



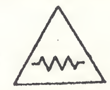
Capacitive Reactance

Inductive Reactance

L-C Circuit with Infinite Reactance at Resonance



L-C Circuit with Zero Reactance at Resonance

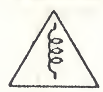


Resistance


Equivalent Shunt Element-General

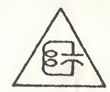
Capacitive Susceptance

Conductance



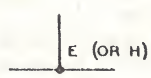
Inductive Susceptance

L-C Circuit with Infinite Susceptance at Resonance

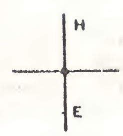


L-C Circuit with Zero Susceptance at Resonance

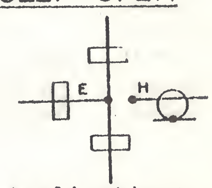
## JUNCTION APERTURE FULLY OPEN




Tee or Wye




Hybrid



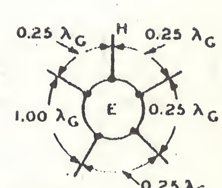

Application: Waveguide and Coaxial Couplings

Hybrid, Circular

(1) Letter inside circle indicates plane of the field in the ring is normal to the axis of the ring.

(2) If arm has coupling different from (1), it should be marked accordingly.

(3) Critical distances should be labeled in terms of guide wavelengths.




Application: 5-arm Circular Hybrid

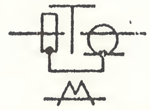
**MODE SUPPRESSION**

**MODE TRANSDUCER**

Mode Transducer

Applications:

Transducer from Rectangular to Circular Waveguide

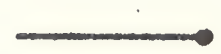


Transducer for Rectangular Waveguide to Coaxial with D-C Grounds Connected and Made Suppression

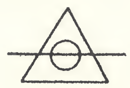
**MOVABLE**



**OPEN** (SEE COUPLING BY PROBE)

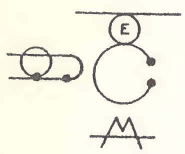


**PHASE SHIFTER**

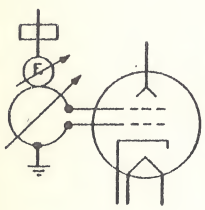


**RESONATOR** (EXCLUDING PIEZO-ELECTRIC AND MAGNETOSTRICTION DEVICES)

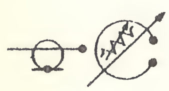
Resonator




Reasonator Coupled by an Aperature to a Guided Transmission Path and by a Loop to a Coaxial With Mode Suppression.




Resonator, Attached to an Electronic Device, With Variable Coupling by an Aperature to Rectangular Waveguide. With Variable Tuning and d-c Ground Connected.



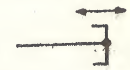
Resonator Coupled by a Probe to a Coaxial. With Tuning. Variable Q.

Applications

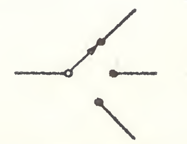
**ROTATION**

**SHORT** (TRANSMISSION PATH TERMINATED IN A SHORT)

Movable Short



**SWITCH** (ANY NUMBER OF TRANSMISSION PATHS MAY BE USED)

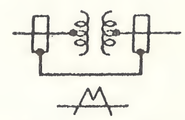


**TEST POINT** (WHERE IT IS INTENDED THAT THE GUIDED TRANSMISSION PATH MAY BE BROKEN FOR TEST OR MEASUREMENT)



(a) If it is important, that d-c paths be open, a note may be added.
(b) Connector types may be indicated.

**TRANSFORMATION FOR TAPERS AND STEP TRANSFORMERS WITHOUT MODE CHANGE**

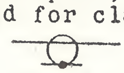


Transfer With D-C Ground Connections and Mode Suppression

Application:

**TRANSMISSION PATH GUIDED**

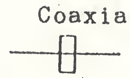
A single line represents a transmission path and extends for its entire length. The recognition convention is used at the beginning and the end of each kind of transmission path, and its intermediate points as needed for clarity. Mode may be indicated.



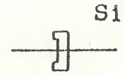
Coaxial



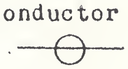
Single Conductor



Rectangular Waveguide



Ridged Waveguide



Circular Waveguide

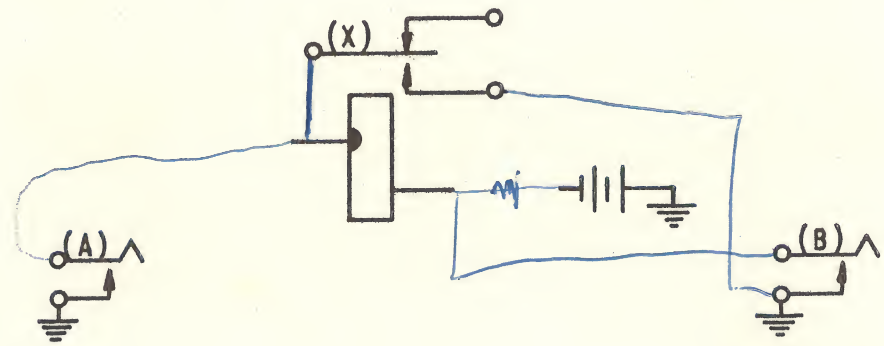
COAXIAL AND WAVEGUIDE CONVENTIONS

# SYSTEMS CIRCUIT ELEMENTS 144

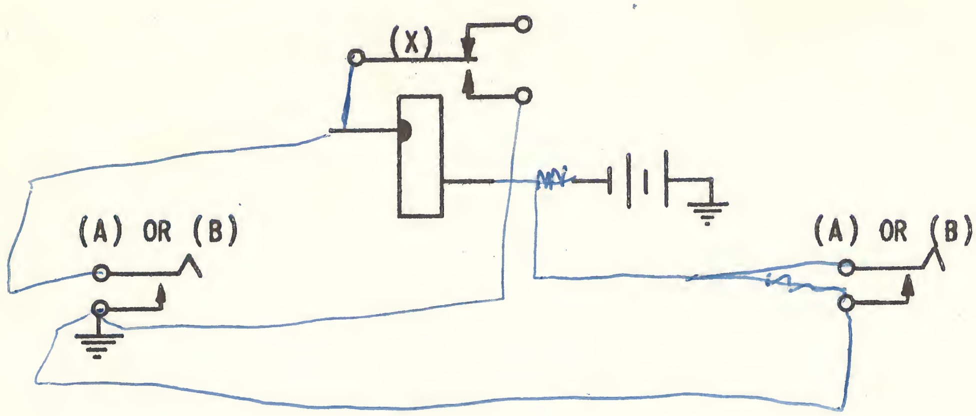
## BASIC RELAY CONTROL PROBLEMS

MAKE RELAY (X) OPERATE WHEN SWITCH "A" IS OPERATED AND REMAIN OPERATED WHEN "A" IS RESTORED. MAKE RELAY (X) RELEASE WHEN SWITCH "B" IS OPERATED. RELAY (X) SHALL THEN REMAIN RELEASED UNTIL SWITCH "A" IS AGAIN OPERATED. GROUNDS OTHER THAN THOSE SHOWN SHALL NOT BE PLACED ON THE SWITCH CONTACTS AND ADDITIONAL CONTACTS SHALL NOT BE PLACED ON RELAY (X). ONE RESISTANCE MAY BE ADDED IF REQUIRED.

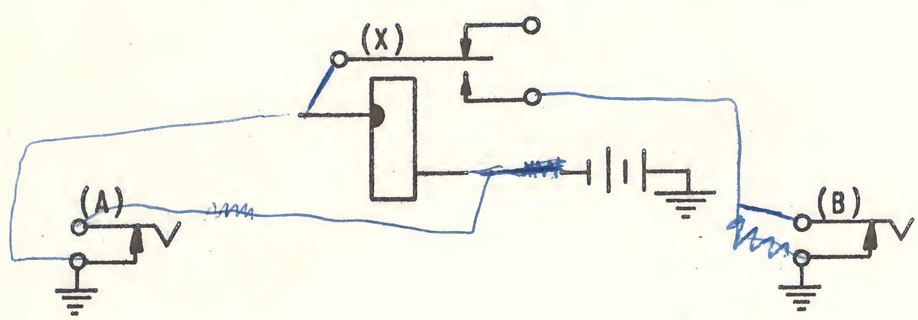
PROBLEM 1




PROBLEM 2



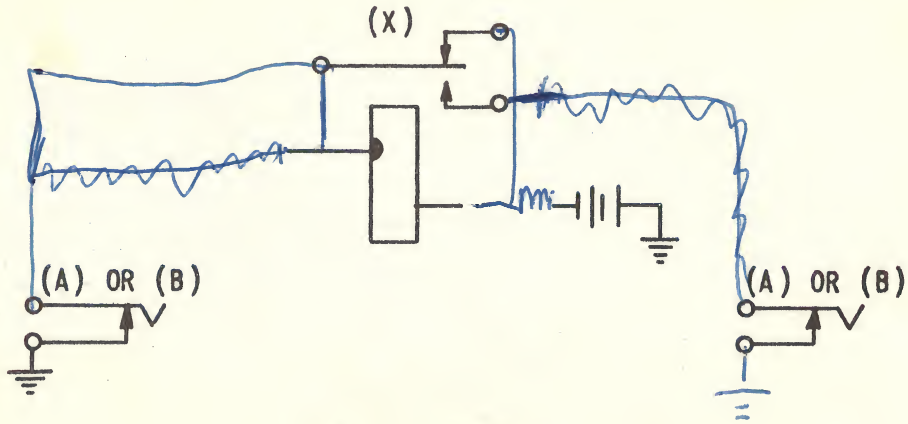

PROBLEM 3



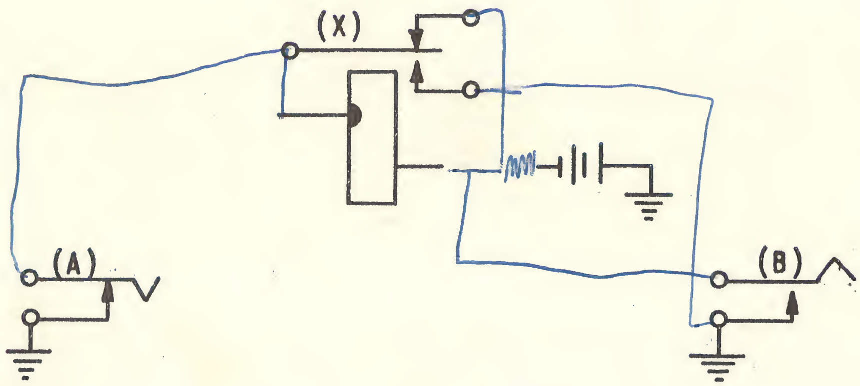
# SYSTEMS CIRCUIT ELEMENTS 144

## BASIC RELAY CONTROL PROBLEMS (CONT'D)

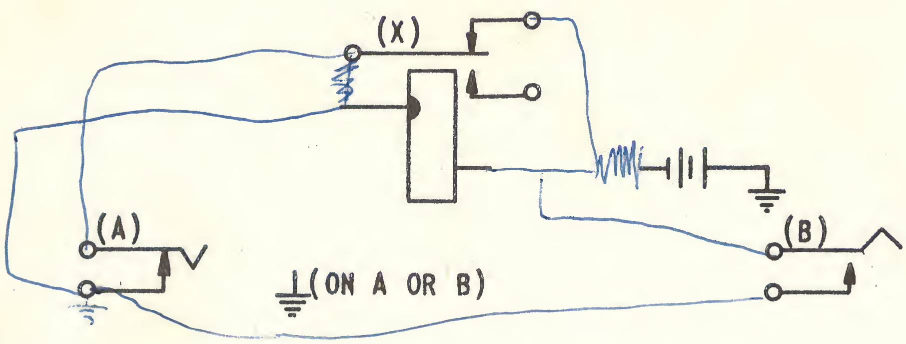
PROBLEM 4



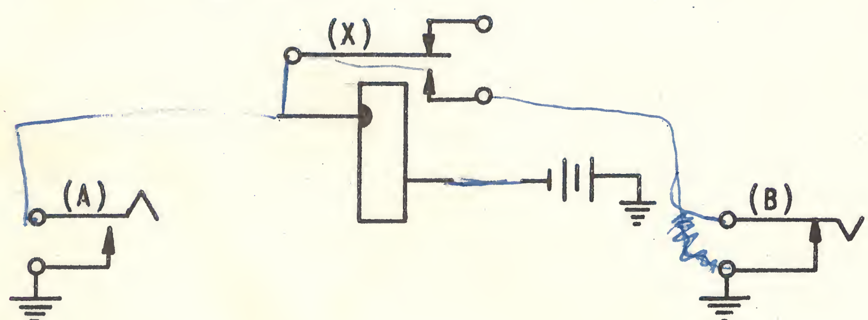

PROBLEM 5




PROBLEM 6



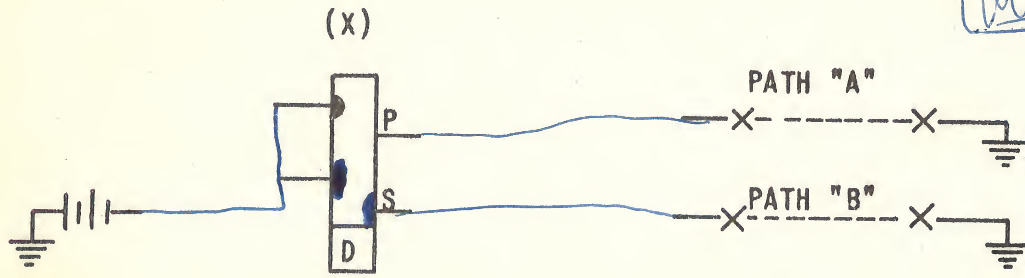

PROBLEM 7



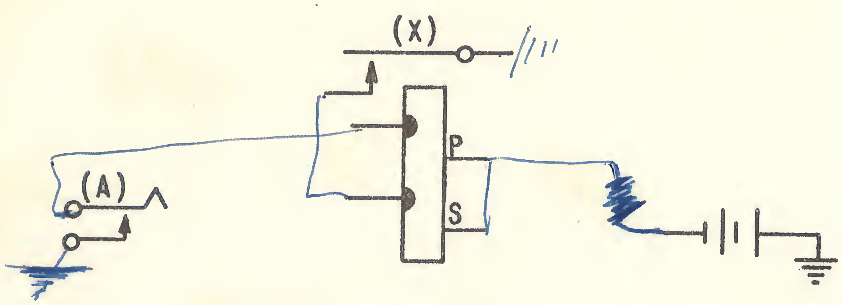
Sense dot - used to indicate the relative winding
direction to simplify whether
the windings will be aiding or
opposing

## SPECIAL PURPOSE RELAY CONTROL PROBLEMS

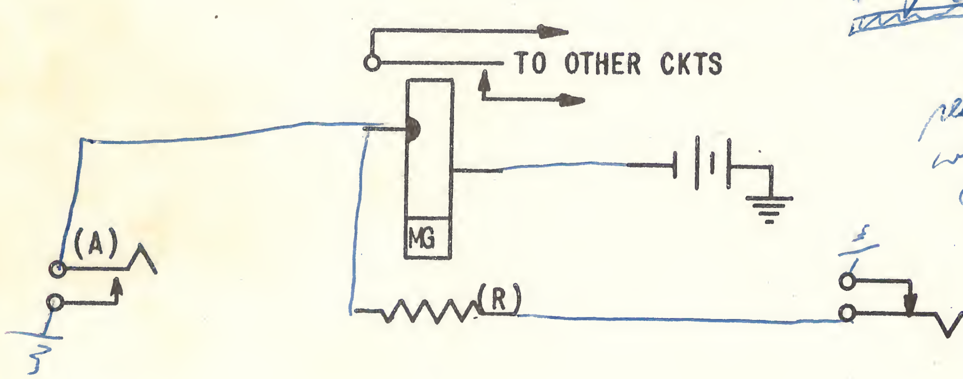
1. RELAY (X) IS BALANCED DIFFERENTIAL RELAY. CONNECT THE CIRCUIT BELOW IN SUCH A MANNER THAT RELAY (X) WILL ONLY OPERATE WHEN EITHER PATH "A" OR "B" IS OPEN OR GROUNDED




2. RELAY (X) IS A DOUBLE WINDING RELAY. CONNECT THE CIRCUIT BELOW IN SUCH A MANNER THAT RELAY (X) WILL OPERATE WHEN SWITCH "A" IS OPERATED AND THEN REMAIN OPERATED WITH REDUCED HOLDING CURRENT WHEN SWITCH "A" IS RELEASED.




3. RELAY (X) IS A MARGINAL RELAY. OPERATE RELAY (X) BY CLOSING KEY "A". RELAY (X) SHALL REMAIN OPERATED WHEN KEY "A" IS RELEASED. THE RELAY SHALL BE RELEASED BY OPERATING KEY "B". DO NOT USE RELAY CONTACTS IN THE CIRCUIT CONTROL PATHS.




resistor in series with relay & reduce current

GRADUATE ENGINEERING TRAINING

## SYSTEMS CIRCUIT ELEMENTS 144
## BASIC RELAY CONTROL PATHS

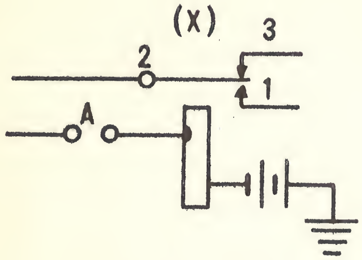



FIG.1

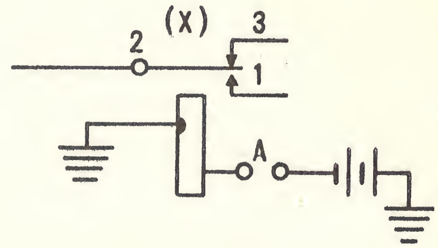



FIG.1A

CLOSING OF CIRCUIT AT "A" OPERATES RELAY (X)

DIRECT CONTROL

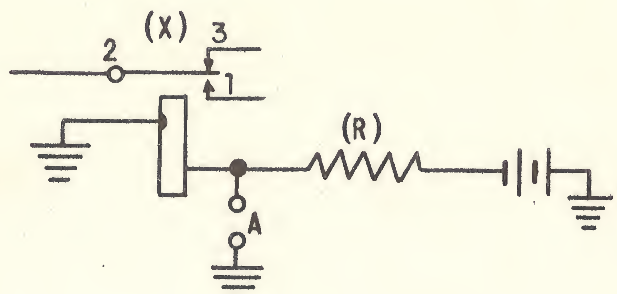



FIG.2

OPENING OF CIRCUIT AT "A" OPERATES RELAY (X)
CLOSING OF CIRCUIT AT "A" RELEASES RELAY (X)

SHUNT CONTROL

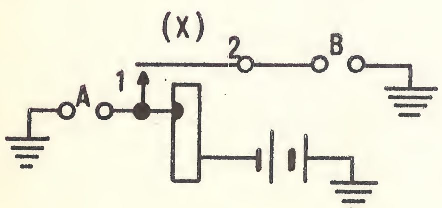



FIG.3A

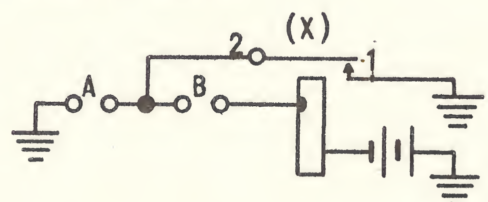



FIG.3B

IN FIG.3A AND 3B

RELAY (X) LOCKS UP THROUGH OWN CONTACTS WHEN "A" IS CLOSED WHILE "B" IS CLOSED. RELAY (X) IS RELEASED WHEN "B" IS OPENED.

LOCK UP CONTROL

## SYSTEMS CIRCUIT ELEMENTS 144

### BASIC RELAY CONTROL PATHS

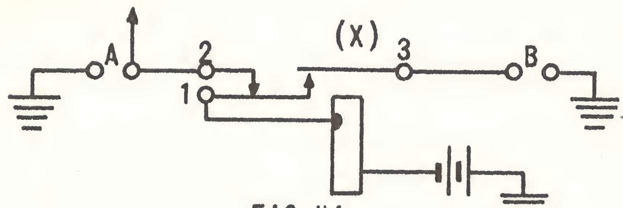



FIG.4A

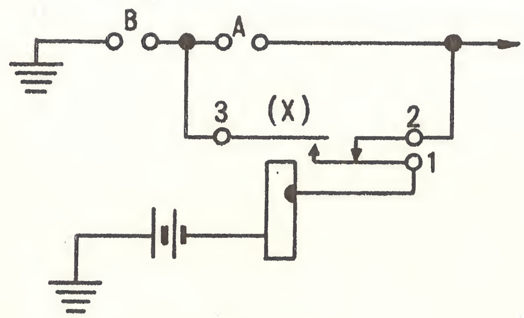



FIG.4B

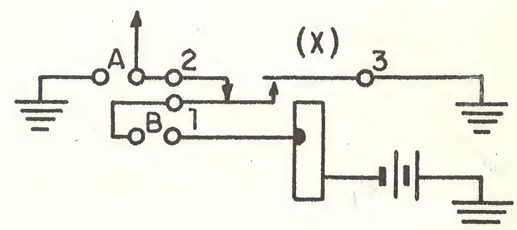



FIG.4C

IF "A" IS CLOSED WHILE "B" IS CLOSED RELAY (X) OPERATES AND LOCKS UP. WHEN "A" IS OPENED RELAY (X) STAYS OPERATED UNTIL "B" IS OPENED.

CONTINUITY LOCK UP CONTROL

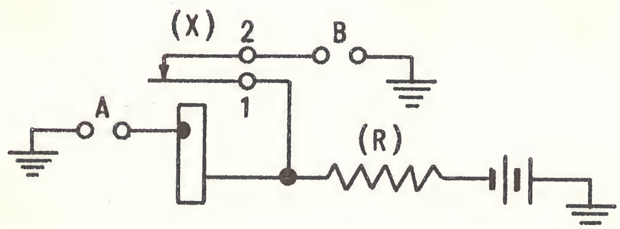



FIG.5A

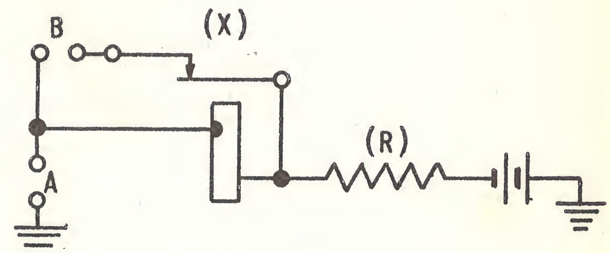



FIG.5B

RELAY (X) CANNOT OPERATE UNTIL "B" IS OPENED. IT CAN THEN OPERATE WHEN "A" IS CLOSED AND REMAIN OPERATED UNTIL "A" IS OPENED.

LOCK DOWN CONTROL

BASIC RELAY CONTROL PATHS

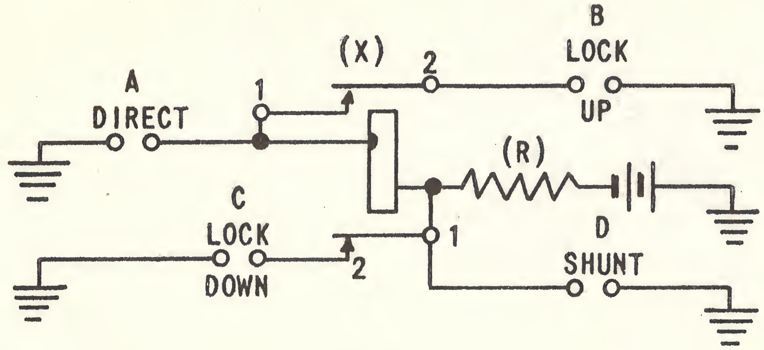



FIG.6

RELAY (X) CANNOT OPERATE WHEN "A" IS OPEN OR "C" OR "D" CLOSED.

COMBINED BASIC CONTROL CIRCUITS

MARGINAL relay

made to operate on current value

& will not operate on current below
~~operate~~ operate value

used in series with other relays

allows detection of more than one condition on

a pet of leads

Semi Dot

1- inner end of winding closest to core

2- usually goes to ground (except polar & differential

3- indicates polarity

## SYSTEMS CIRCUIT ELEMENTS 144

## CONTROL PATHS OF SPECIAL PURPOSE RELAYS

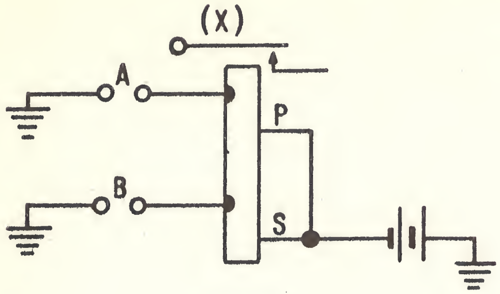



FIG.1

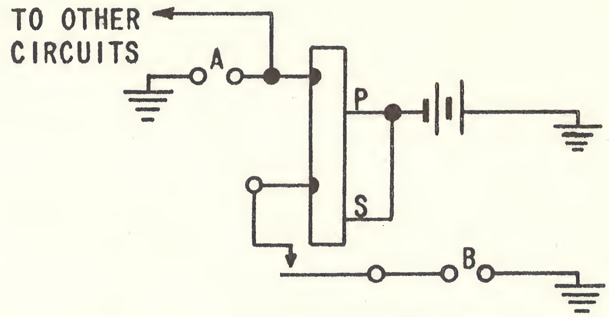
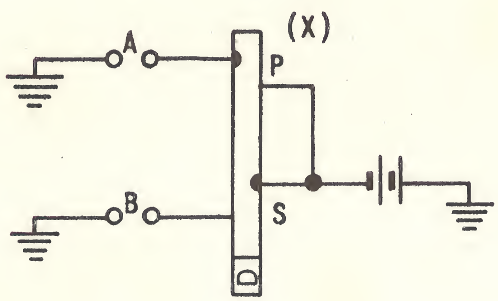



FIG.1A

IN FIG.1 EITHER OR BOTH PATHS "A" AND "B" WILL OPERATE RELAY (X) WITHOUT INTERFERING WITH EACH OTHER.

IN FIG.1A OPERATING PATH OF RELAY (X) IS COMPLETELY ISOLATED FROM THE LOCKING PATH.

### MULTIWOUND RELAY CONTROL




P AND S WINDINGS ARE IDENTICAL

RELAY (X) CAN BE OPERATED BY CLOSING EITHER "A" OR "B"

RELAY (X) CAN BE RELEASED BY CLOSING BOTH "A" AND "B"

FIG.2

### DIFFERENTIAL RELAY CONTROL

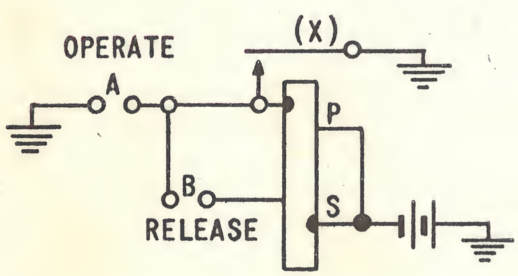



FIG.3

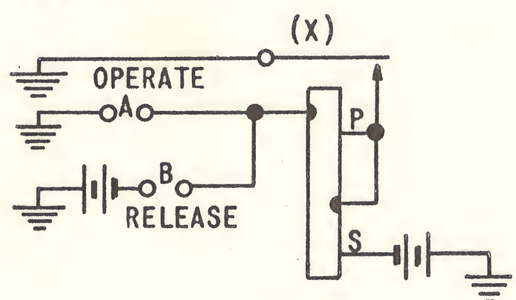



FIG.3A

RELAY (X) OPERATES AND LOCKS UP WHEN "A" IS CLOSED. RELAY (X) WILL RELEASE WHEN "B" IS CLOSED (PATH "A" MUST BE OPEN).

### FORCED RELEASE OF RELAYS

## CONTROL PATHS OF SPECIAL PURPOSE RELAYS

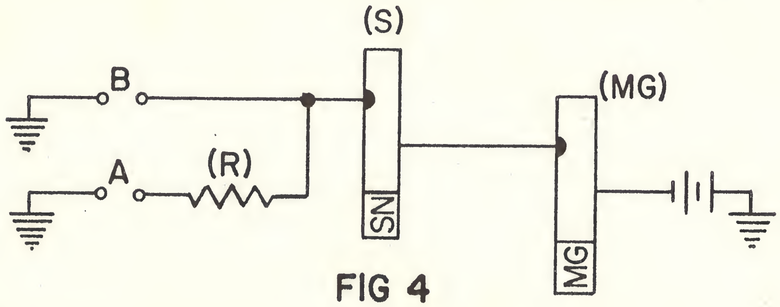
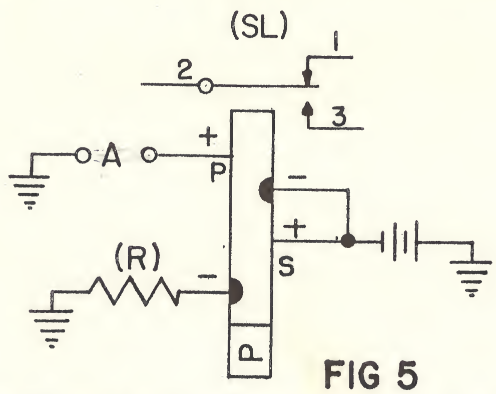



FIG 4

WHEN "A" IS CLOSED ONLY RELAY (S) WILL OPERATE.
WHEN "B" IS CLOSED BOTH RELAYS (S) AND (MG) WILL OPERATE.

## CONTROL OF MARGINAL AND SENSITIVE RELAYS




Telegraph — sends out pos. & neg

signs are relative polarity

FIG 5

"S" WINDING OF RELAY IS BIASING WINDING AND WHEN ENERGIZED ALONE HOLDS ARMATURE AGAINST CONTACT 1.

WHEN "A" IS CLOSED RELAY WILL OPERATE TO CONTACT 3.

## CONTROL OF POLAR RELAY WITH BIASING WINDING

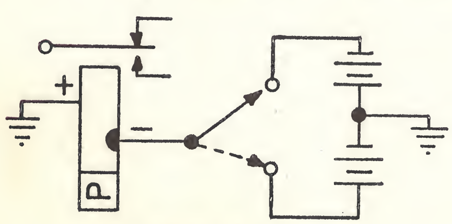



FIG 6

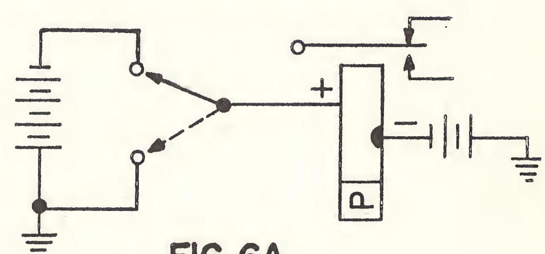
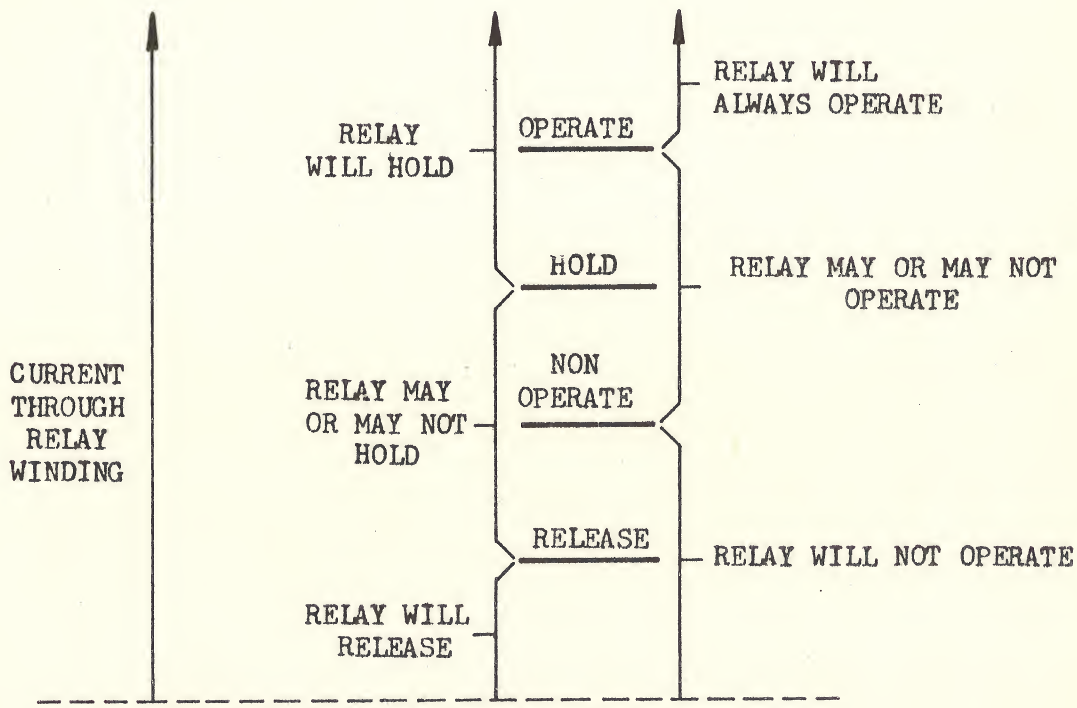



FIG 6A

## METHODS OF REVERSING FLUX IN POLAR RELAYS

# SYSTEMS CIRCUIT ELEMENTS 144

## RELAY OPERATING CHARACTERISTICS




RELATIONSHIP AMONG RELAY ADJUSTMENTS

<u>RELAY REQUIREMENTS</u>

1. <u>OPERATE</u> - CURRENT LEVEL AT WHICH RELAY WILL <u>DEFINITELY</u> OPERATE.

2. <u>HOLD</u> - LEVEL TO WHICH CURRENT CAN BE REDUCED AFTER RELAY HAS OPERATED AND STILL INSURE THAT RELAY REMAINS FULLY OPERATED.

3. <u>NON-OPERATE</u> - CURRENT LEVEL AT WHICH AN UNOPERATED RELAY DEFINITELY WILL NOT OPERATE.

4. <u>RELEASE</u> - LEVEL TO WHICH CURRENT THROUGH AN OPERATED RELAY CAN BE REDUCED WITH ASSURANCE THAT THE RELAY WILL COMPLETELY RETURN TO AN UNOPERATED CONDITION.

GOOD Definitions for EXAM

# SYSTEMS CIRCUIT ELEMENTS 144

ROTARY SELECTOR SWITCH CONTROL
(204 & 206 TYPE SWITCHES)

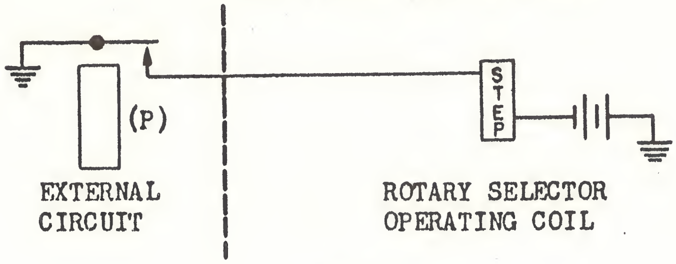



FIG. 1

STEP MAGNET IS ENERGIZED BY EACH CLOSURE OF MAKE CONTACTS ON RELAY (P).

IF STEP SWITCH IS FORWARD ACTING IT WILL STEP AT BEGINNING OF GROUND PULSE.

IF STEP SWITCH IS BACK ACTING IT WILL STEP AFTER THE STEP MAGNET IS DE-ENERGIZED.

## DIRECT STEPPING

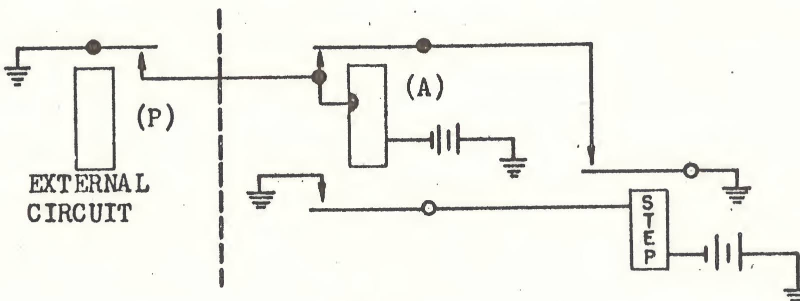



FIG. 2

THE BREAK CONTACT OF THE STEP MAGNET IS ADJUSTED SO THAT IT DOES NOT OPEN UNTIL PAWL OF STEP SWITCH HAS MOVED REQUIRED DISTANCE.

## METHOD OF LENGTHENING INPUT PULSES

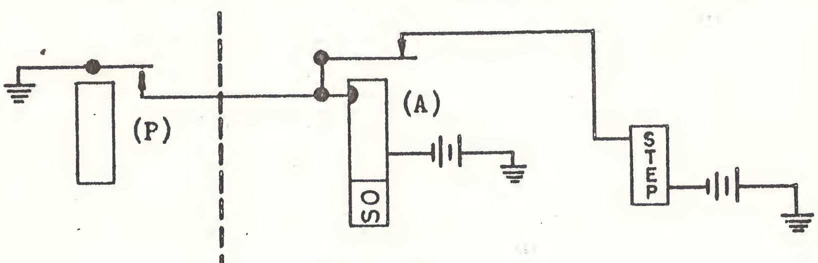



FIG. 3

GROUND IS APPLIED TO THE STEP MAGNET ONLY DURING THE TIME IT TAKES RELAY (A) TO OPERATE

## METHOD OF SHORTENING INPUT PULSES

GRADUATE ENGINEERING TRAINING

# SYSTEMS CIRCUIT ELEMENTS 144

ROTARY SELECTOR SWITCH RUNNING AND RESTORING CIRCUITS
(TYPE 204 AND 206 SELECTORS)

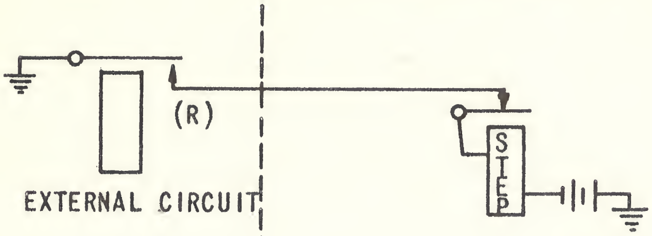
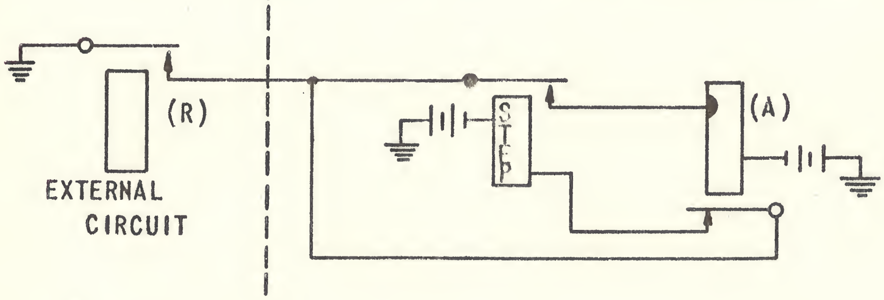


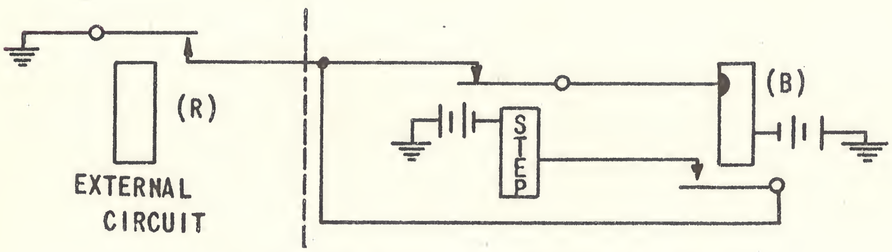

FIG 1

DIRECT RUNNING, SELF INTERRUPTED CIRCUIT




THROUGH MAKE CONTACT ON STEP MAGNET

FIG 2




THROUGH BREAK CONTACT ON STEP MAGNET

FIG 2A

SLOW RUNNING SELECTOR CIRCUITS

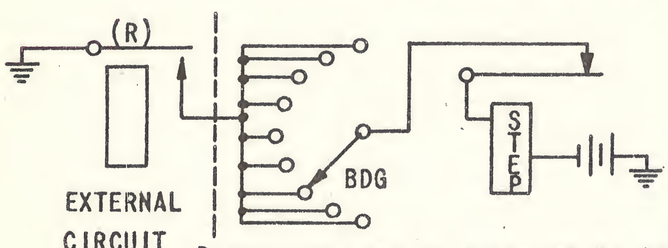



FIG 3

DIRECT HALTING OF SELECTOR BY ABSENCE OF GROUND

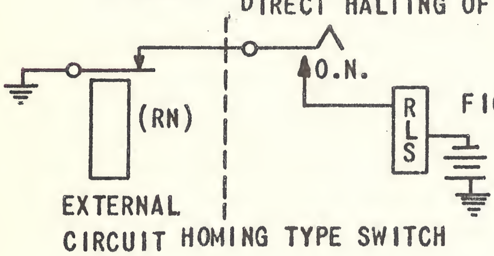



FIG 4

HOMING TYPE SWITCH

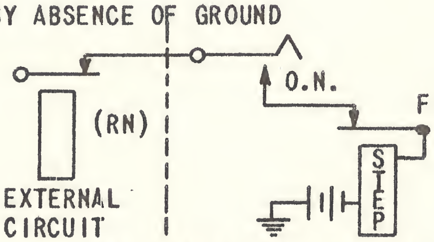



FIG 4A

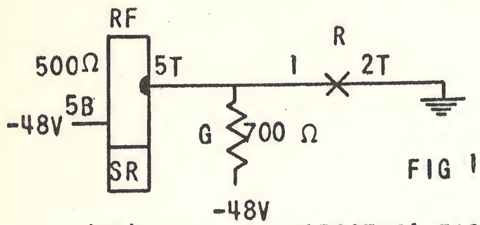
NON HOMING TYPE SWITCH

SELECTOR SWITCH RESTORING CIRCUITS

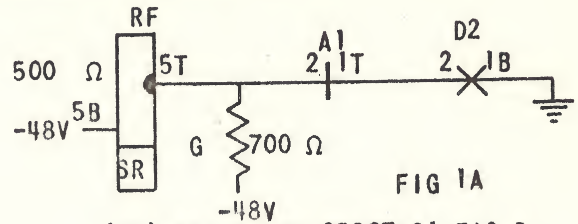
GRADUATE ENGINEERING TRAINING

# SYSTEMS CIRCUIT ELEMENTS 144

CIRCUIT SHORTS-OPERATING PATHS OF RELAYS ON SD-25887-01




(RF) REL IN SD-25887-01 FIG E




(RF) REL IN SD-25887-01 FIG D

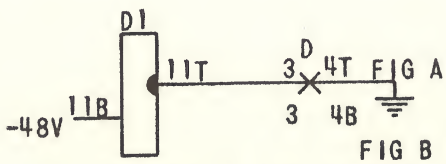
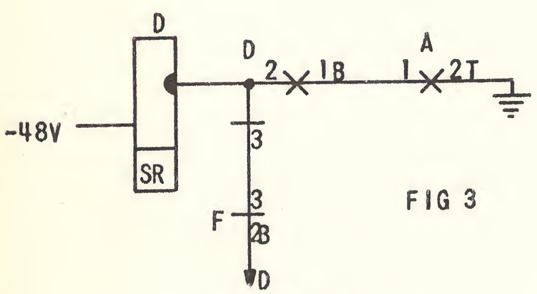


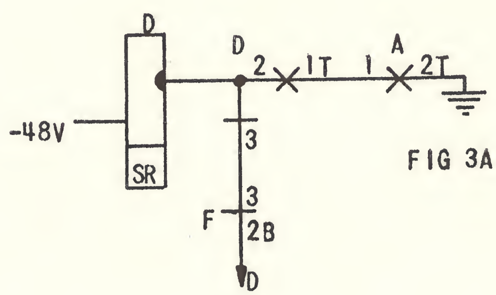

FIG 2

(D1) REL IN SD-25887-01 FIG 1

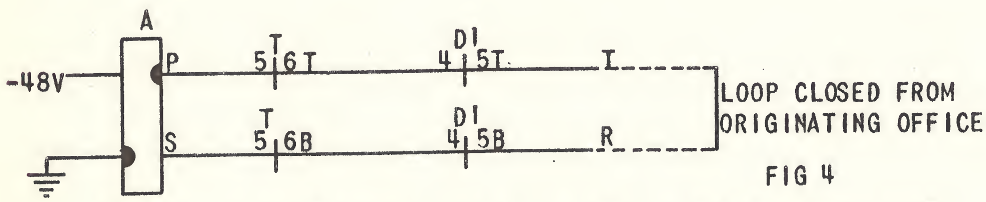



TO SDR LK
GRD FURNISHED WHEN
SDR COMPLETES OUTPULSING

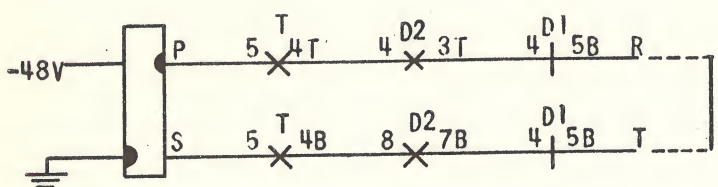
(D) REL IN SD-25887-01 FIG A




(D) REL IN SD-25887-01 FIG B



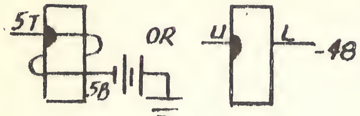

(A) REL IN SD-25887-01 FIG 1 (T AND D1 REL NOT OPERATED)



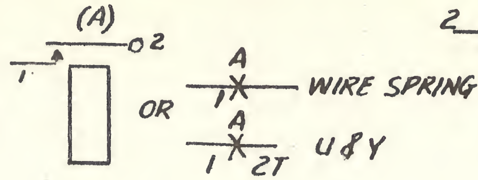

(A) REL IN SD-25887-01 FIG 1 (T AND D2 REL OPERATED)

# SYSTEMS CIRCUIT ELEMENTS 144

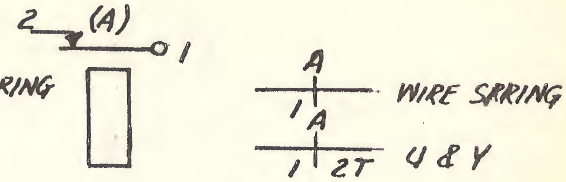
## RELAY CONTACT COMBINATIONS AND CONVENTIONS



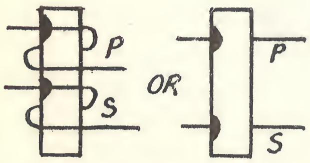

CORE & WINDING



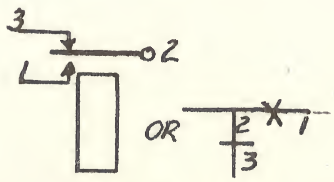

MAKE CONTACTS



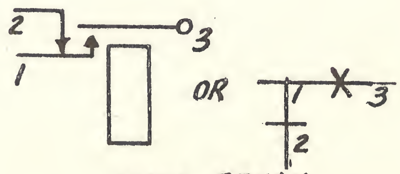

BREAK CONTACTS



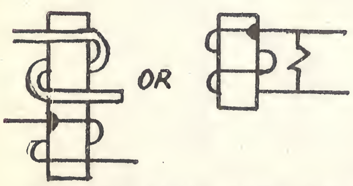

DOUBLE WINDING



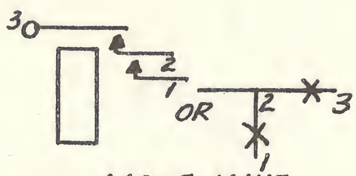

BREAK-MAKE
OR TRANSFER



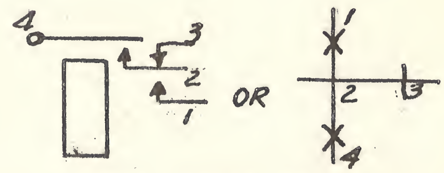

MAKE-BREAK
OR CONTINUITY TRANSFER




RELAYS WITH NON-INDUCTIVE
WINDINGS



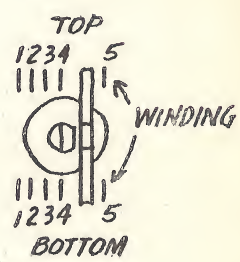

MAKE-MAKE



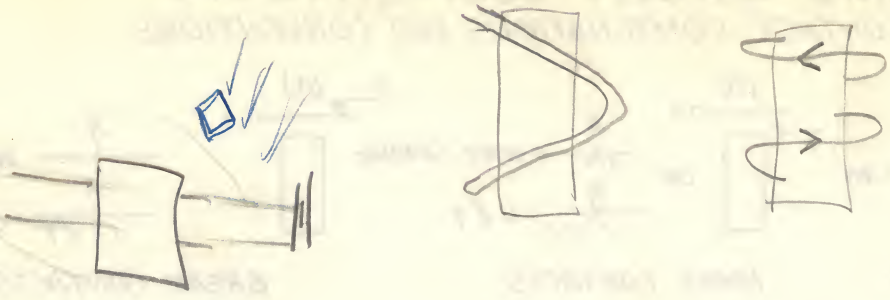

MAKE-BREAK-MAKE

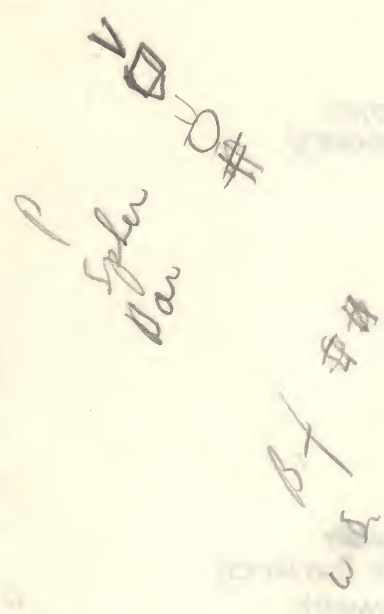
WIRE SPRING CONTACT TYPES AND SEQUENCE CHARACTERISTICS
(SHOWN ON DETACHED CONTACT SCHEMATIC APPARATUS FIGURES)

- M - MAKE
- B - BREAK
- EM - EARLY MAKE
- EB - EARLY BREAK
- BM - BREAK MAKE (NON SEQUENCE TRANSFER)
- EBM - EARLY BREAK MAKE (SEQUENCE TRANSFER)
- EMB - EARLY MAKE BREAK (CONTINUITY TRANSFER)
- PM - PRELIMINARY MAKE
- PB - PRELIMINARY BREAK
- PMEB - PRELIMINARY MAKE-EARLY BREAK (PRELIMINARY TRANSFER WITH RESPECT TO LATE CONTACTS)
- PBEM - PRELIMINARY BREAK-EARLY MAKE (PRELIMINARY CONTINUITY TRANSFER WITH RESPECT TO LATE CONTACTS)




U & Y TYPE
CONTACT SPRING
NUMBERING





What is a relay (def)
Parts of an electric mag relay
Types of windings (How const, worked, use)
Draw spring combination
Contacts (function of, limitation & adv of types of contacts)
How do we protect contacts
3 Factors which effect oper Time
3 " " " release time
4 ELECTRICAL Req (oper, hold, release, non-operate)
Use of A Relay
why LAMINATED CORE
4 Diff Betwn U & Y TYPE WIRE Spring Relay
(Diff bet AG, AH, AJ
IMP. IN MAG. STRUCTURE